A comparison of root canal preparation using Er:YAG and Er,Cr:YSGG laser: a light microscopic and scanning electron microscopic report

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Statement by Research Supervisor of MDSc Thesis or Research Project

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Professor L.J. Walsh

(Research Supervisor)

Declaration statement

I, Edward Barton Rutley of 17 Mozart Place, Mount Ommaney, solemnly declare that the work presented in this report is, to the best of my knowledge and belief, original, except as acknowledged in the text. Although the articles contained are multi-authored and contribution of the co-authors is greatly appreciated, their input was mainly advisory and I carried out the bulk of the laboratory work and writing. The material presented has not been submitted, either in part or in whole for another degree at this or any other university.

Declared by:	Witnessed by:
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Paper 1

Title

An evaluation of root canal preparation comparing Er:YAG and Er,Cr:YSGG lasers: Part 1 (light microscopy)

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Abstract

Background: Laser root canal preparation techniques are mainly experimental. However, the US FDA recently approved Er,Cr:YSGG laser for clinical use in preparing root canals. The aim of this study was to assess and compare root canal preparation by Er:YAG and Er,Cr:YSGG lasers.

Methods: 102 extracted human teeth were randomly allocated to 4 groups: the NiTi Group prepared by rotary NiTi; the Er:YAG Group prepared by Er:YAG laser; the Er,Cr Group prepared by Er,Cr:YSGG laser; and the Unprepared Group. Teeth were bisected, photomicrographed and scored according to predefined criteria. Data were analysed by the Mann-Whitney U Test, and Chi-square analysis.

Results: Assessment of the overall quality of root canal preparation found: the NiTi Group was superior to the other groups ($P<0.0083$); the Er,Cr Group was not different from the Unprepared Group ($P= 0.181013$); and the Er,Cr and Unprepared Groups were superior to the Er:YAG Group ($P<0.0083$). Also, the NiTi Group was associated with clean, smooth, and well formed preparations ($P<0.05$); and the Er:YAG Group was associated with rough and irregular preparations with procedural errors ($P<0.05$).

Conclusions: The Er:YAG and Er,Cr:YSGG laser root canal preparations were not comparable to the rotary NiTi preparations. The experimental Er:YAG laser preparations were unsatisfactory. Furthermore, the Er,Cr:YSGG laser preparations could not be differentiated from the unprepared controls.

Introduction

A key requirement for successful root canal treatment is adequate shaping of the root canal to facilitate the irrigation process during root canal preparation and to simplify the obturation process.[1, 2]

Moreover, guidelines from peak endodontic bodies state that the primary objectives of root canal instrumentation are the elimination of the residual pulp tissue, the removal of debris and the maintenance of the original canal curvature during enlargement.[3, 4]

Endodontic applications of various lasers are becoming increasingly popular in endodontics. Numerous investigations of lasers in endodontics have dealt with pulpal extirpation, shaping of root canals, apical sealing and laser apicoectomy sealing.[2, 5]

A variety of lasers have been developed and applied in dentistry, they include: semiconductor diode, carbon dioxide (CO_2), helium-neon (HeNe), neodymium:yttrium-aluminium-garnet (Nd:YAG), argon, erbium (Er:YAG), and erbium, chromium: yttrium-scandium-gallium-garnet (Er,Cr:YSGG).[5, 6]

Smear layer and debris can be removed from root canals when appropriate laser wavelengths and operating parameters are used.[7, 8] Furthermore, Er:YAG laser irradiation has been demonstrated to be more effective in removing debris on root canal walls than the Argon, CO_2 or Nd:YAG laser.[9-13] However, lasers have only been used after the root canals had already been enlarged to a minimum of a size 40 K-type file and in conjunction with an irrigation solution of sodium hypochlorite,

known to effectively dissolve loose organic debris from the root canal.[14-16]

Some pulsed laser devices produce cavitation effects in root canals in a manner similar to that of the ultrasonic irrigator.[13, 17] At present, the effect is weaker than that of ultrasonic irrigation; this laser technique is likely to be improved in the future. Straight and slightly curved root canals as well as wider root canals are indications for this treatment. The pulsed Nd:YAG laser, Er:YAG laser, and ErCr:YSGG laser are recommended, but the laser fibre still requires slight improvement.[5]

Lasers, such as carbon dioxide and Nd:YAG surgical lasers, have a well recognized destructive effect on bacteria, and this has led to the development of techniques for sterilising wounds, carious lesions and root canals.[18, 19] Others, have shown the beneficial effects of laser treatment in disinfecting root canals.[19-21] Whereas, conventional endodontic treatment is not fully effective due to microbial colonization of root canal walls.[22, 23] Thus, when appropriate laser wavelengths and operating parameters are used there is the possibility of one-step disinfection, including of anaerobic micro-organisms.

Therefore, when the numerous attributes of lasers in endodontics are taken in combination, there is a potential for using lasers to prepare root canals through shaping, cleaning, debris removal, smear layer removal and sterilisation of the root canal with one instrumentation sequence. There is potential to reduce or eliminate the need for special irrigation solutions, intra-canal medicaments and complicated instrumentation methods.

In 1992, Levy [17] described a technique to prepare root canals with an Nd:YAG laser and compared these preparations to a conventional hand-file technique. Levy observed the potential for a laser beam to prepare a tapered root canal preparation and to remove debris.

However, Cohen et al [24] were the first to describe in detail, an endodontic laser technique to prepare a root canal using a Ho:YAG laser. They suggested:

1. Scouting the canal with a size 15 K-type file.
2. ‘Step back’ with the laser fiberoptic guide starting at 140µm fibre, then a 245µm fibre, then a 355µm fibre and finally a 410µm fibre. The fibres will be inserted to the apex, energised and then withdrawn slowly at about 4mm/sec.
3. The active cutting laser energy was directed away from the long axis of the fiberoptic guide in the shape of an annular ring. In this configuration, there was no cutting energy in the centre of the ring. In affect, the lateral walls of the canal will be lased, not the apical area. This lasing configuration was accomplished using a proprietary optical setup in the laser itself.

The laser root canal preparation technique described by Cohen et al [24] is an apical-coronal root canal preparation technique with many of the disadvantages of such a technique, such as: lack of early coronal access results in greater potential for debris extrusion; less access for irrigants to apical areas early in preparation; poor tactile discrimination at apex due to coronal binding of files; and poor early straight line access to the apex.

Therefore, one of the objectives of this study was to prepare root canals using Er:YAG laser with an experimental coronal-apical root canal preparation technique and avoiding many of the limitations of an apical-coronal root canal preparation technique.

Er,Cr laser has recently been approved by the US FDA for use in endodontics and is being promoted as suitable for preparing root canals.[25-28] The root canal preparation technique with this laser is an apical-coronal technique similar to the technique described by Cohen et al. [24] However, this technique does not purely rely on the laser to prepare the root canals and is in reality a hybrid technique that relies largely on the use of conventional root canal preparation techniques such as hand files to prepare the apical seat of the root canal preparation and then uses laser to shape the root canal.

Erbium is a metallic element of the rare-earth group that occurs with yttrium and is also used as a source of laser irradiation. An Er:YAG laser (Key Laser®, KEY Laser 1242, KaVo Dental GmbH, Jena Germany) is a solid state, pulsed laser that has a maximum emission in the mid-infrared region at 2.94µm. Water absorbs strongly in this region. The pulse energy of this unit can vary from 20mJ/pulse to 600mJ/pulse and the power output can be up to 6W. The laser is delivered through fiberoptic tips that have terminal diameters of 285, 375 or 470µm.

Whereas, the Er,Cr:YSGG laser (Millennium system, Biolase Technology, Inc; San Clemente, California) uses a pulsed laser energy source delivered through a sapphire tip that is bathed by an air/water

spray. It operates at a wavelength of 2.78μm and the power output can be up to 6.0W. The laser is delivered through fiberoptic tips that have a terminal diameter of 200, 320, 400 or 800μm. The fiberoptic tips are bathed in an adjustable air/water spray. This device generates precise hard tissue cuts by virtue of laser energy interaction with water above and at the tissue interface, and it has therefore been termed a hydrokinetic system (HKS).[29]

A number of recent studies are similar to the proposed study.[12, 24, 30-33] However, none of these studies have compared the use of different lasers such as Er:YAG and Er,Cr:YSGG to prepare root canals, and none have been compared with currently accepted root canal preparation techniques such as rotary NiTi instruments.[34, 35]

The aim of this study was to investigate root canal morphology after laser treatment using newly developed fibre optic endodontic handpieces with flexible and thinner laser fibres.

Therefore, this study tested the hypothesis that root canals prepared with either Er:YAG laser or Er,Cr:YSGG laser were comparable to more popular root canal preparation techniques (NiTi rotary instruments); in terms of the degree of preparation and debris removal, as assessed microscopically.

Material and methods

160 extracted human teeth were randomly drawn from a well mixed collection of extracted single-rooted teeth from the Supervisor's laboratory stock that were stored in Brisbane tap water. The teeth were

drawn by an independent person who was blinded to the study's objectives. The teeth were thoroughly mixed in the "barrel" in between each draw.

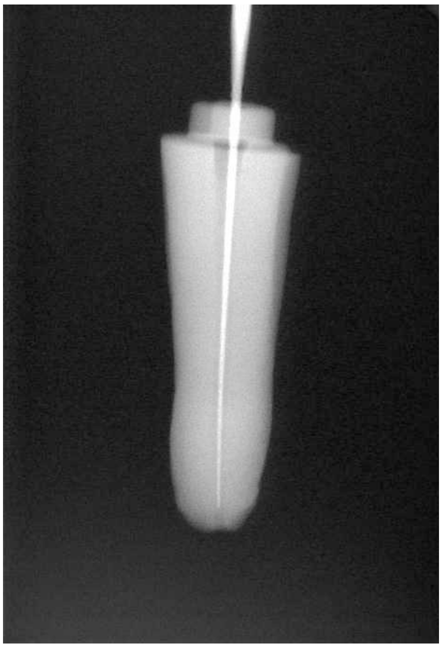
The teeth were extracted because they were badly decayed and unrestorable or for periodontal reasons. Therefore, the teeth were decoronated to standardise coronal access preparations. A size 10 K-type file was introduced into the canal until it appeared at the apical foramen to assess for inclusion into the study. The working length was established by subtracting 1mm from this length.

Teeth were further assessed for inclusion into the study by digital radiographic screening (the digital radiographic unit was Sirona Heliodent DS, D3334 and D3302, Sirona Dental Systems GmbH, Bensheim, Germany; and digital radiographic software was Sidexis Next Generation V 1.2, Sirona Dental Systems GmbH, Germany). The screening radiographic examination involved taking two periapical radiographs, one from the buccolingual view and one from the mesiodistal view (Figure 1).

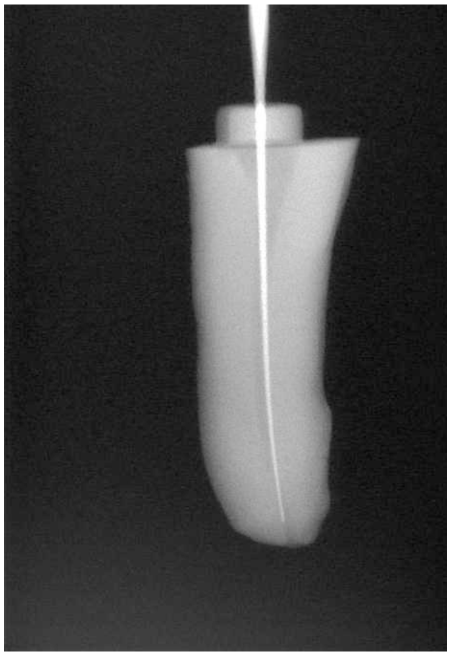
Teeth were finally excluded if they did not have a single patent canal; simple root canal anatomy; uncomplicated apical anatomy; only a single mild root canal curvature; and suitable working length.

Figure 1. Representative digital periapical radiographs of a specimen allocated to the NiTi Group, the buccolingual view is seen in a) and the mesiodistal view is seen in b)

a)



b)



58 teeth did not meet the study inclusion criteria and were excluded from the study (Figure 6). In summary, the teeth were excluded for the following reasons:

1. previously undetected root canal fillings (n=8);
2. multiple root canals were present (n=22);
3. root canals were blocked (n=1);
4. unusual root canal anatomy (n=1);
5. evidence of apical resorption (n=2);
6. acute apical root canal curvature (n=4);
7. prominent and extensive apical deltas were present (n=2);
8. s-shape root canal was present (n=2);

9. there was evidence of incomplete root formation (n=1);

10. unusual apical root canal anatomy (n=1); and

11. extreme working length (i.e. W/L<11mm, W/L>17mm) (n=16).

Estimated data were analysed using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA) to determine that group sample sizes of 60 and 60 achieve 80% power to detect a difference of 1.3 between the null hypothesis that both group means are 9.3 and the alternative hypothesis that the mean of the Er:YAG Group is 8.0 with known group standard deviations of 2.0 and 2.0 and with a significance level (alpha) of 0.0083 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

The significance level of 0.0083 was used because the desired significance level for the study was 0.05. Accordingly, to compensate for multiple comparisons between the means of 4 independent groups, this significance level was reduced from 0.05 to 0.0083.

In other words, based on 0.8 power to detect a significant difference (P=0.0083, two-sided) 60 effective specimens were required for each study group. However, each specimen was evaluated by 3 different evaluators creating an actual group sample size of 20 teeth.

Additionally, to compensate for lost teeth, 25 teeth (100 teeth in total) in each group were required.

All teeth had an equal probability of assignment to the groups and were randomly allocated to the 4 groups. A computer random number generator was used to generate a random number from 1 to 4 and the

teeth were then allocated to each group in sequence until all had been allocated to the 4 groups. Thus, those teeth of varying levels of root complexity were distributed evenly amongst the 4 groups.

The teeth were allocated to 4 groups:

1. the NiTi Group, prepared with rotary NiTi files and used as positive controls;
2. the Er:YAG Group, prepared with Er:YAG laser root canal preparation techniques;
3. the Er,Cr Group, prepared with Er,Cr:YSGG laser root canal preparation techniques; and
4. the Unprepared Group, were left unprepared and used as negative controls.

Interventions

The following interventions were implemented on the different study groups.

Er,Cr:YSGG Group

Er,Cr:YSGG laser (Waterlase™, Millennium, Biolase Technology Inc, San Clemente, CA, USA) was used as recommended by the manufacturer.[25-28, 36]

In summary, the root canal preparation technique [27, 36] was:

1. Glide path establishment: a glide path was established and the apex was enlarged to at least a size 25 K-type file.

2. Root canal debridement: a Z2 (200µm) fibre tip was used 1-2mm short of WL (allow for optimum ablation distance); the tip was aimed at the side of the root canal; the tip was placed, activated and ablation occurred as the tip was withdrawn over 8sec; as the tip is withdrawn a sweeping motion was used; the tip was replaced into the canal and aimed at a different part of the root canal ready for another pass; a total of 6 ablation passes were made, simulating a circumferential filing concept.

3. Root canal shaping: a Z3 (320µm) fibre tip was used as in 2, above; followed by a Z4 (400µm) fibre tip that was used as in 2, above; the root canal was enlarged until a size 35 K-type file fitted easily to working length.

4. Saline irrigation was used in copious quantities.

The parameters used with the Er,Cr:YSGG laser throughout the study have been tabulated (Table 1).

Table 1 Er,Cr:YSGG laser parameters

Procedure	Tip	Power (W)	Water (%)	Air (%)
root canal debridement	Z2 (200µm)	1.5 (<2.5)	24	34
root canal shaping	Z3 (320µm)	1.5 (<2.5)	24	34
root canal shaping	Z4 (400µm)	1.5 (<2.5)	24	34

Er:YAG Group

Er:YAG laser Key Laser® (KEY Laser 1242, KaVo Dental GmbH, Jena Germany) was used in an experimental technique developed by the authors.

This experimental technique was developed for this study to discover if a coronal-apical root canal preparation technique could be used successfully in vitro. This experimental technique was based on the following previously described techniques: the crown-down pressureless technique;[37] the balanced force technique;[38] and the double flared technique.[39]

The objectives of this coronal-apical technique were to: produce early coronal flaring with special emphasis on reducing apical extrusion of debris; and to facilitate preparation of curved canals without causing deviation or zipping.

In summary, the experimental Er:YAG laser root canal preparation technique was:

1. Scout the coronal 2/3s of the canal with hand files.[40, 41]
   Determine radicular access length to a depth to which a size 30 K-type file penetrates to its point of first resistance. The coronal portion of the canal should be prepared to this length.
2. Pre-enlargement of the coronal 2/3s:[40, 41] straight line access was established with a 50/10 fibre tip; and radicular access preparation by using a #1 band fibre tip, followed by a #2 and then #3 band fibre tip, taken to the radicular access length without any apical force.
3. Scout the apical 1/3 of the canal and verify the glide path with hand files:[40, 41]

a. Place a size 30 K-type file into the canal until it encounters resistance. Use balanced force technique. Repeat, using a 25 K-type file and then successively smaller files until the working length is reached.

b. This completes the first instrumentation sequence, which began with a size 30 K-type file at the radicular access length and finish with the largest file that passively reached the working length.

c. A second instrumentation sequence began with a file one size larger than the file that began the previous sequence (i.e. a size 35 K-type file). This was used with balanced force technique and successively smaller files inserted and similarly rotated until the working length was reached. The file at the apical seat should be a size larger than in the first sequence.

d. Further sequences of instrumentation were performed until the apical file was a minimum of a size 30 K-type file.

4. Finish the apical 1/3 preparation,[40, 41] the #1, #2 and #3 band fibre tips were used. The root canals were finished with a 0.10 taper as suggested in balanced force technique [38] by stepping back with 1mm increments between successively larger fibre tips. Preparation of the apical third of the canal to the appropriate size using the step-back technique means that there is much less filing

is necessary to establish the final taper. Once again, the use of recapitulation is stressed.[39]

5. The diameter of the foremen was gauged to confirm completion of canal preparation.[40, 41] The apical 1/3 preparation was refined as indicated, (#2 and #3 band fibre tips if indicated).

6. Copious irrigation with saline was used throughout the procedure.

The parameters used with the Er:YAG laser throughout the study have been tabulated (Table 2). The Er:YAG laser was used with a Key Laser® 3 endodontic handpiece 2062 and the parameters used were based on the manufacturer recommendations for settings to cut dentine during restorative procedures.

Table 2 Er:YAG laser parameters

Fibre insert	Diameter (mm)	Length (mm)	Energy (mJ)	Frequency (Hz)	Air	Water
#1 band, 30/28	0.285	28	500	4	Y	N
#2 band, 40/28	0.375	28	450	4	Y	N
#3 band, 50/28	0.470	28	450	4	Y	N
#3 band, 50/10	0.470	10	500	4	Y	N

NiTi Group

Rotary K3 files (SybronEndo, West Collins, CA, USA) were used with a 4:1 reduction handpiece (WE-66 EM, W&H, Buermoos, Austria) powered by a torque-limited electric motor (Endo IT motor, VDW, Munich, Germany). For each file, the torque and speed programmed in the file library of the Endo IT motor were used. The K3 files were used following the crown down technique (variable taper variable tip size)

recommended by the manufacturer. In summary, the rotary NiTi root canal preparation technique was to:

1. Confirm coronal patency
2. Determine apical size by using a radiograph and information from step1, estimate final apical size and taper.
3. Begin crown down with a file 3 sizes larger than the intended final apical size.
4. Establish working length after reaching the middle third of the root canal.
5. Complete crown down preparation taking each instrument to resistance. Use each instrument at 300-350rpm for only 5-7 seconds.
6. Copious irrigation with 1% sodium hypochlorite and 17% EDTAC between the introduction of files.[42]

Unprepared Group

The negative control specimens were not instrumented or irrigated except during the initial tooth preparation and assessment for inclusion phase of the study.

After the completion of study interventions, the roots were allowed to air dry.

The roots were bisected into halves by cutting two parallel grooves with a slow-speed carborundum disk on the outer surface of the roots and split with an instrument used as a chisel to prevent contamination of the canals

during the separation process.[43] The roots were fractured so that in a longitudinal direction the main root canal curvature was bisected in one plane. The residual loosely bound pulp tissue was removed by using a blast of air. Thus, the walls of the canals were not touched by instruments or irrigating solutions except as described above.

An additional 6 teeth were excluded from the study. Five teeth were excluded because of root fracture during preparation for photomicrographs and one tooth was excluded because of the presence of previously undiagnosed complex root canal anatomy.

The root half showing the major portion of the canal was chosen for examination by stereoscopy, at a magnification of 30 times (Figures 2 to 5).

To assess the degree of root canal preparation, digital photomicrographs (E995, Nikon Coolpix, Nikon Corporation, Tokyo, Japan) were taken of the teeth under a stereo dissecting microscope (SZH-ILLD, Olympus, Olympus Optical Co Ltd, Japan). Photomicrographs were taken at the coronal, middle, and apical thirds of the root canals and assembled into a slide presentation for evaluation. The quality of root canal preparation was scored in a blinded manner by three evaluators according to the criteria (Table 3).

A flow of study teeth through each stage is shown in the following diagram (Figure 6).

Figure 2 Photomicrographs of a representative tooth from the NiTi Group (original magnification 30x)

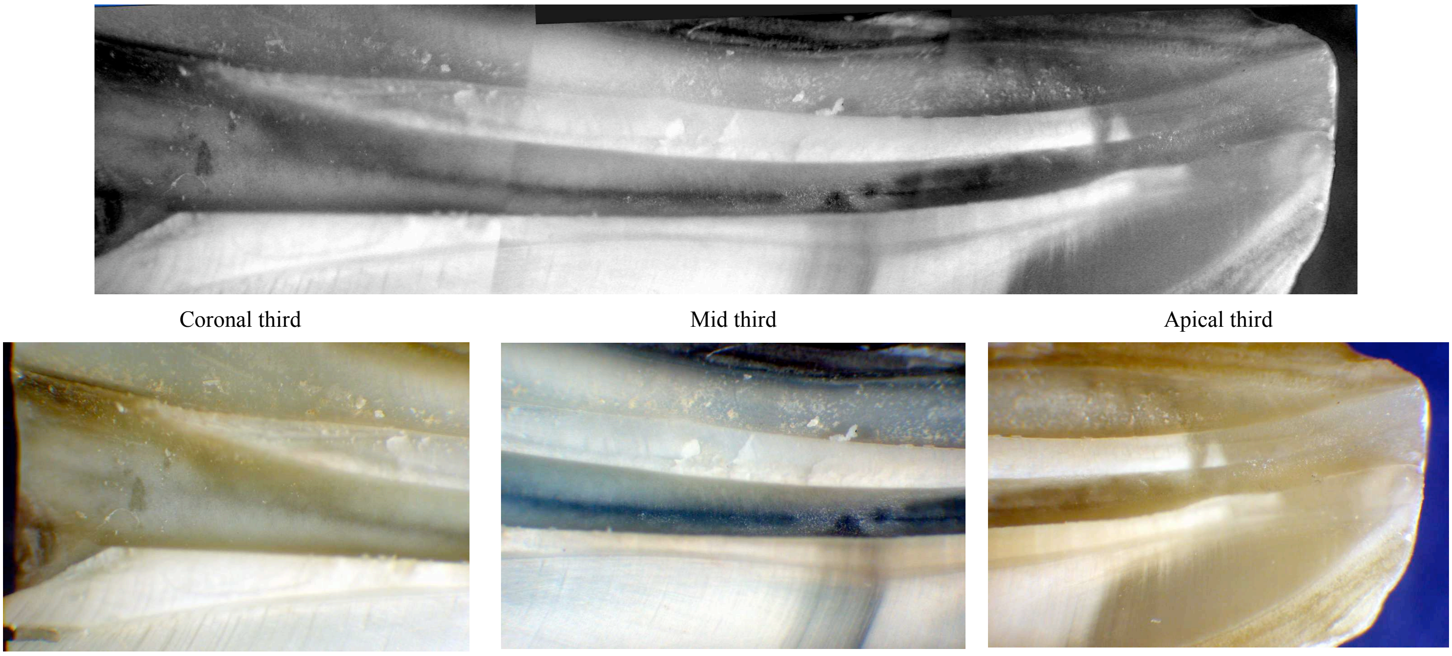


Figure 3 Photomicrographs of a representative tooth from the Er:YAG Group (original magnification 30x)

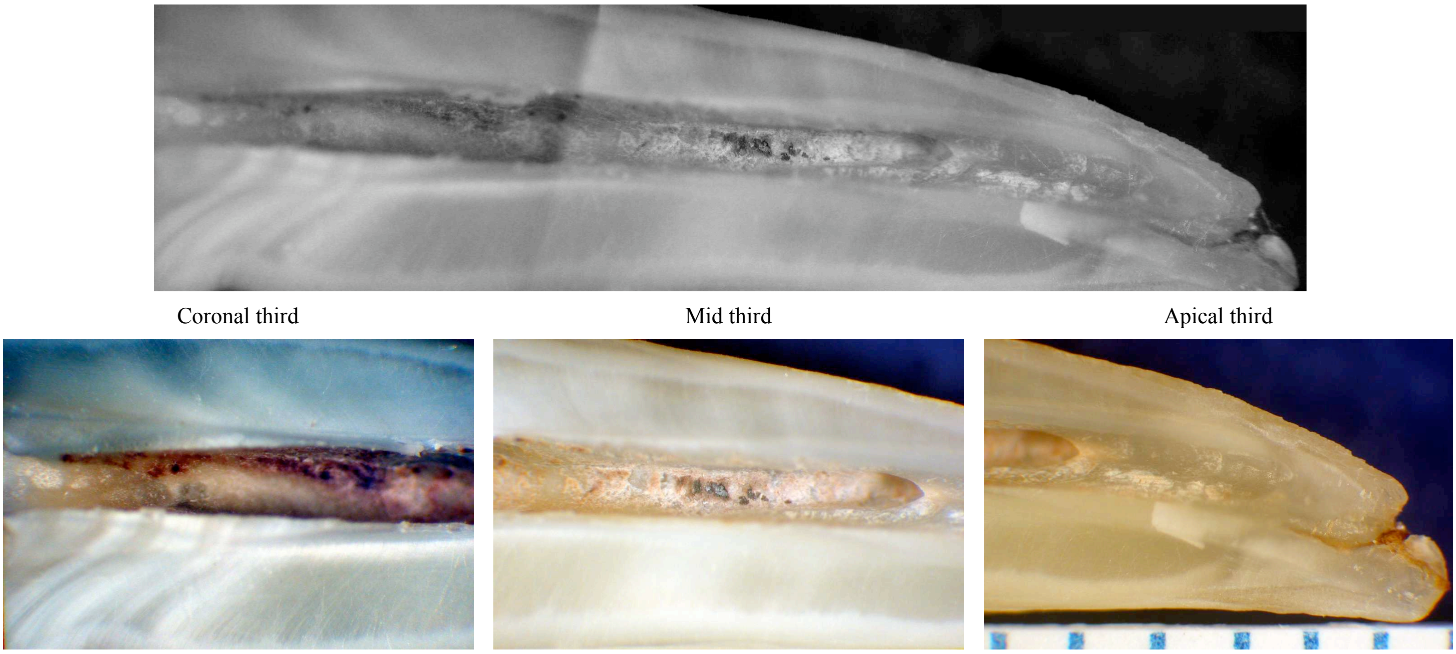


Figure 4 Photomicrographs of a representative tooth from the Er,Cr Group (original magnification 30x)

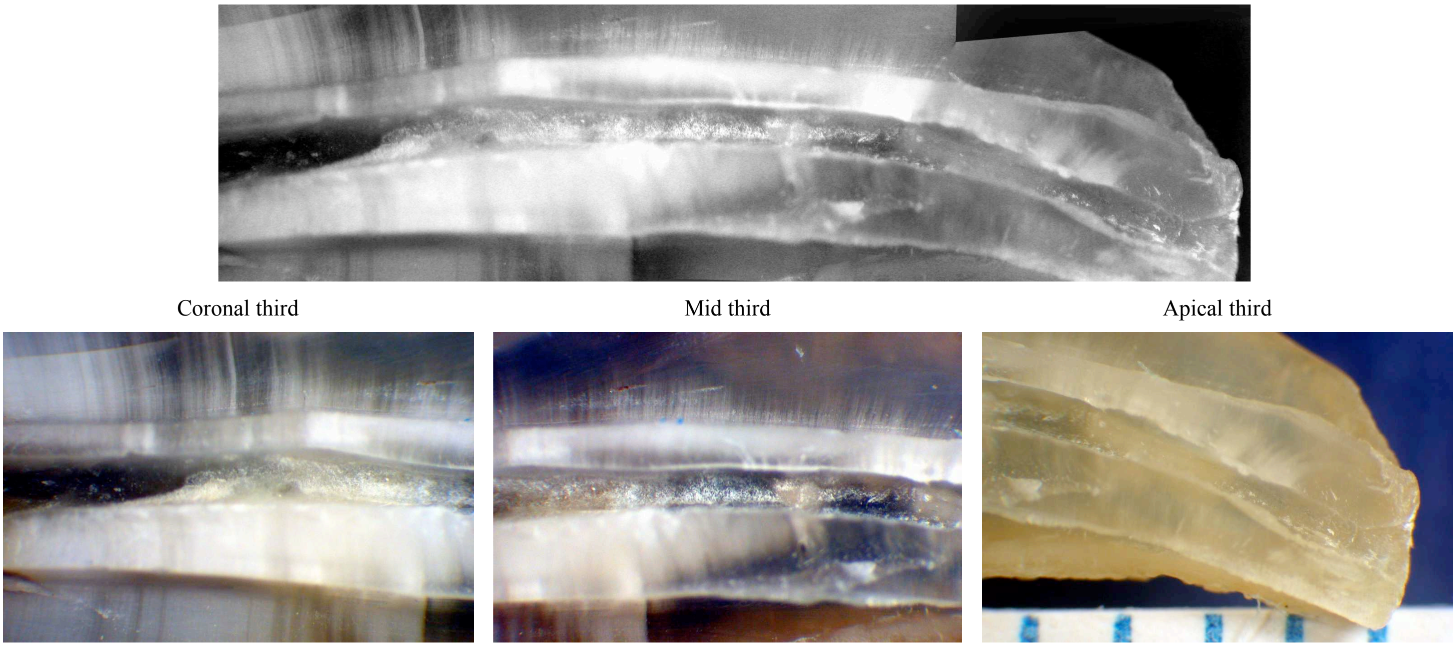


Figure 5 Photomicrographs of a representative tooth from the Unprepared Group (original magnification 30x)

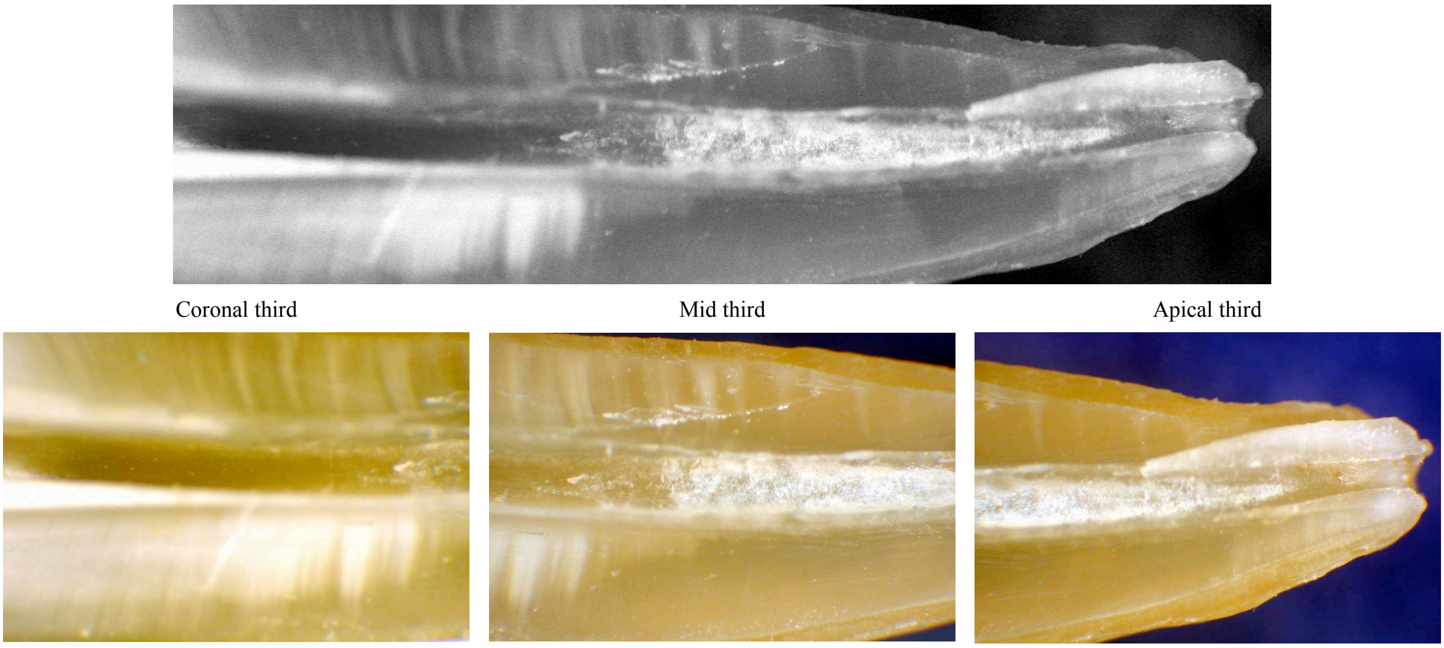
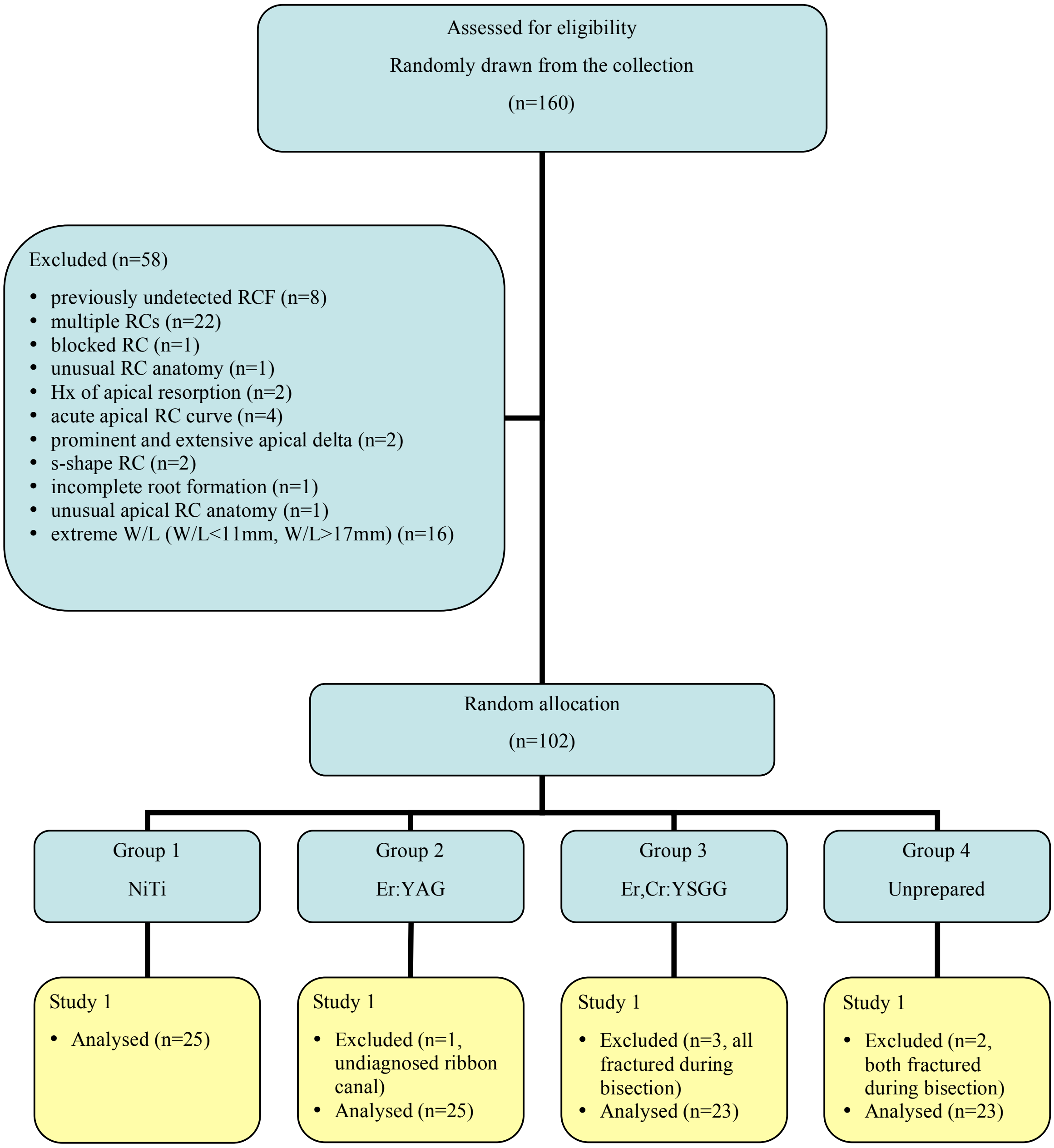


Table 3 The criteria used to evaluate the quality of preparation.

Criteria	Score	Character	Definition
Debris (dentine chips, pulp remnants, and particles loosely attached to the canal wall) [44, 45]	1	Clean (<5%)	Clean canal wall, only very few debris particles
	0	Cover >5%	E.g. few small conglomerations, many conglomerations, or complete or nearly complete covering
Smoothness [46, 47]	1	Good	Smoothness and regularity
	0	Poor	Roughness and irregularity
Apical stop [30, 46-48]	2	Well defined	
	1	Poorly defined	
	0	Absent	
Apical zip [49]	1	Absent	An irregular widened area created by the MAF near the end-point of the preparation where dentin had been removed excessively from the outer aspect of the canal
	0	Present	
Flow [46, 47]	1	Good	A continuous blending of the canal from orifice to apical stop
	0	Poor	Abrupt changes in direction and the presence of ledges
Taper [46, 47]	1	Good	Canal had a conical shape throughout its length
	0	Poor	Hourglass or cylindrical shapes
Elbows [49]	1	Absent	Occurred concurrently with an apical zip and formed a narrower region, more coronally
	0	Present	
Ledges [49]	1	Absent	An irregular area of dentin was removed from the outer aspect of the curved porion of the canal not associated with preparation the end-point. Ledges were always associated with a narrow region more coronally.
	0	Present	
Perforations [49]	1	Absent	Occurred as separate and distinct false canals towards the end-point, along the outer aspect of the curve not confluent with the original canal
	0	Present	

Figure 6 A flow chart of study teeth.



The digital photomicrographs were assembled and randomly sequenced into a slide presentation and evaluated (Experiment 1) by 3 evaluators who did not have previous knowledge of the treatment of the roots or the objectives of the study. The evaluators were trained to assess and score the root canal preparations according to the assessment criteria immediately before the commencement of the slide presentation. Therefore, the judging was without bias.

A second evaluation (Experiment 2) was made one week later. Before the second evaluation, the sequence of the photomicrographs was randomised again without prior knowledge of the evaluators.

Data were recorded directly on score sheets and then stored in a PC notebook (Compaq 800, Compaq Computer Corporation, Intel®, Celeron® CPU 1.70 GHz, 224MB of RAM, Microsoft® Windows® XP Home Edition). The data were analysed using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA).

Results were analysed for statistical significance using Kruskal-Wallis Multiple-comparison Z-value test ($P<0.05$), post hoc comparisons of 2 sample tests using Mann-Whitney U Test ($P<0.0083$, alpha reduced for multiple comparisons) and additional analysis for any associations by chi-square analysis ($P<0.05$).

The assessment criteria were collapsed and analysed according to the following categories: Debris (all root canal thirds were combined), Smoothness (all root canal thirds were combined), Apical stop, Form

(flow and taper), Aberrations (apical zip, ledges, elbows, perforations), and Overall score (total of all criteria).

Results

The box plot illustrates the distribution of overall scores by group for Experiment 1 (Figure 7). The stacked bar chart shows the median overall score by group and the components of the median score by assessed criteria refer to Figure 8. The greater the overall score the better the quality of the clinical root canal preparation.

The Modified-Levene Equal-Variance Test suggested that the assumption of equal variance was not met so the Kruskal-Wallis ANOVA was not valid. The samples were of equal sizes which should compensate for unequal variance.[50] Nevertheless, the alternative Mann-Whitney U test was used with reduced alpha for multiple comparisons.

Statistical analysis by Mann-Whitney U Test ($P<0.0083$) shows that the median overall scores for each of the groups was significantly different. Furthermore, the following statements could be made:

1. The NiTi Group median overall score was significantly greater than the other groups.
2. The Er:YAG Group median overall score was significantly less than the other groups.
3. There was no significant difference between the median overall scores of the Er,Cr Group and the Unprepared Group ($P= 0.181013$).

A cross tabulation and chi square analysis of the data by criteria ($P<0.05$) allowed the following statistical statements to be made:

1. The NiTi Group was associated with clinically clean, smooth and regular root canal surfaces; that are well flowing and tapered root canal preparations ($P<0.05$).
2. The Er:YAG Group was associated with well defined apical stops in the root canal preparations but were also associated with the formation of aberrations within the root canal preparations ($P<0.05$).

These associations between the groups and criteria have been illustrated by histograms (Figures 9 to 13). The greater the score the better the quality of the individual criteria assessed.

A power analysis of Experiment 1 was performed on the difference between the means of the overall score of the Er,Cr Group and the Unprepared Group because their differences were not significantly different. The following statistical statement can be made:

> Group sample sizes of 521 and 521 achieve 80% power to detect a difference of 0.5 between the null hypothesis that both group means are 9.2 and the alternative hypothesis that the mean of the Er:YAG Group is 8.7 with known group standard deviations of 2.4 and 2.4 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

In other words, under the conditions of this study each group would need to have included 174 teeth (521 observations), a total of 696 study teeth so that there was a statistical power of 80% to detect a difference between the 4 groups with an overall significance level of 0.05.

A Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task nevertheless, the Kappa reliability test between evaluators shows fair agreement (Table 4).[50]

Table 4 Kappa reliability test between evaluators

Kappa	Evaluator 1	Evaluator 2	Evaluator 3
Evaluator 1	1.0	-	-
Evaluator 2	0.503234	1.0	-
Evaluator 3	0.558669	0.523316	1.0

In addition, a Spearman rank correlation was calculated to assess intra-evaluator reliability between Experiment 1 and Experiment 2. The Spearman rank correlation was calculated for overall score (r_s=0.771764) and by convention demonstrated a very good to excellent relationship.[50]

Figure 7 A box plot of overall score by group.

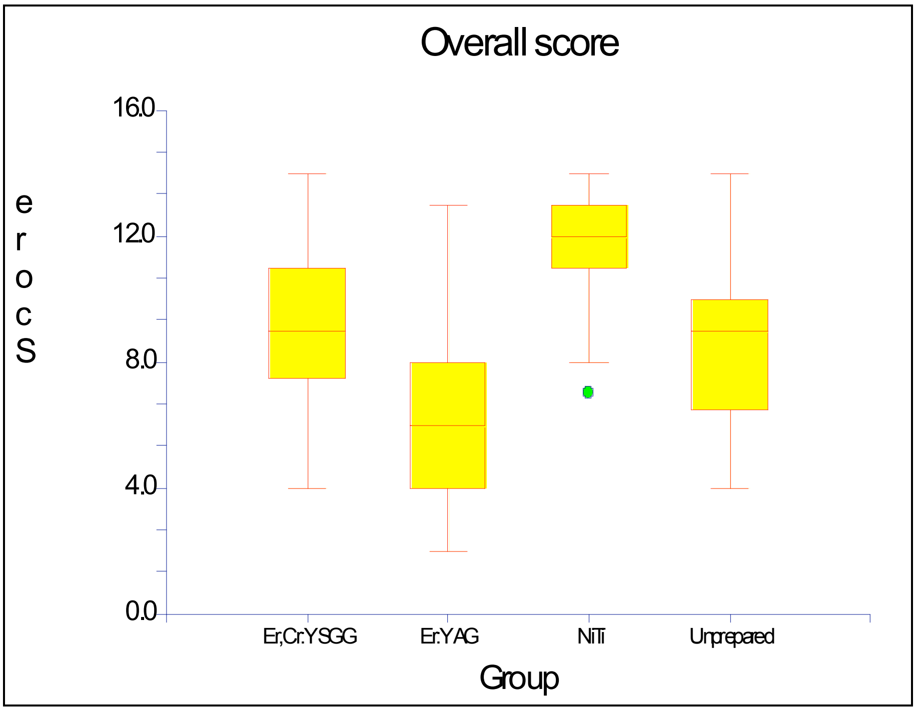
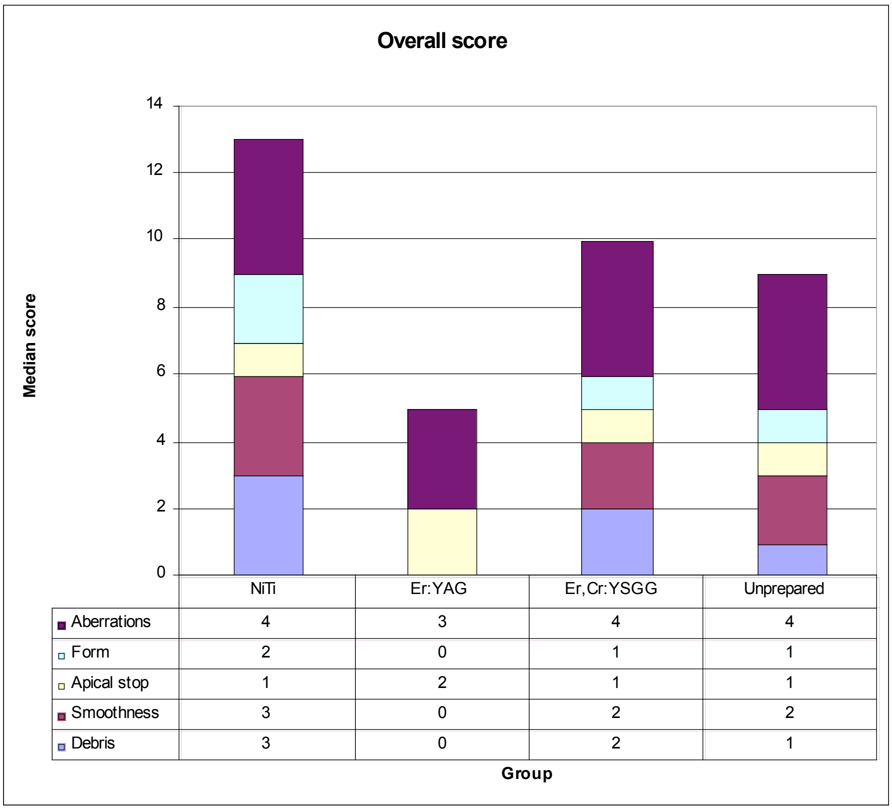
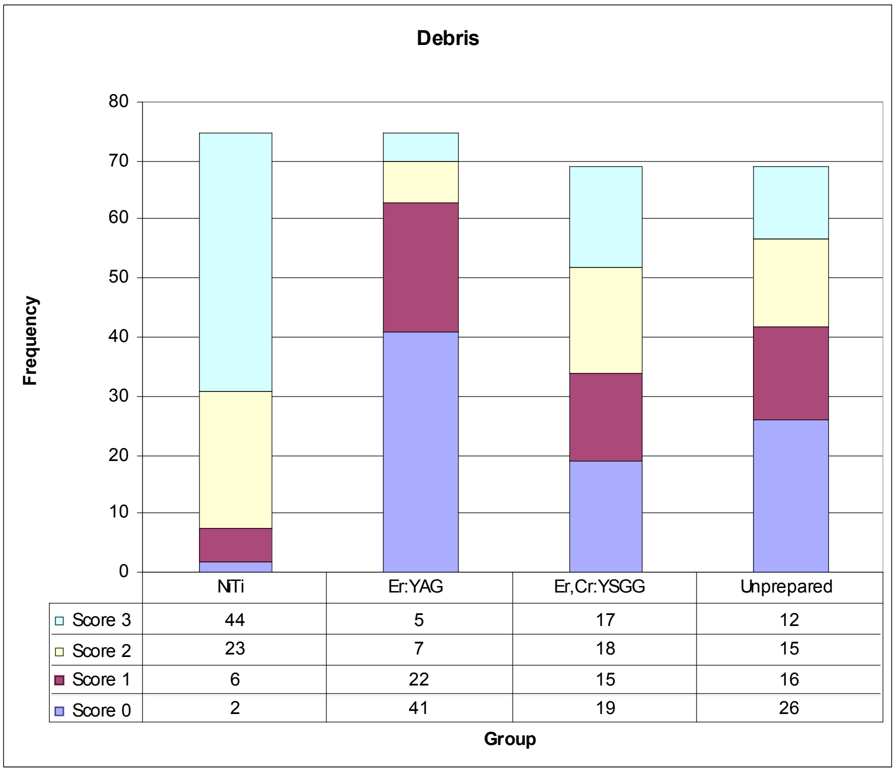


Figure 8 A bar chart of median overall score by group.



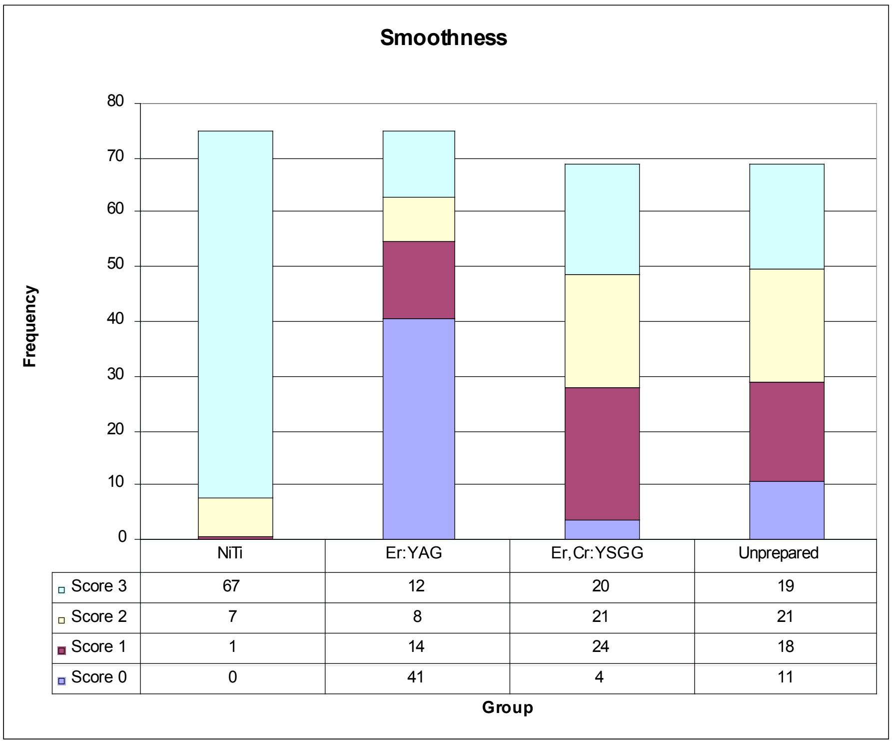
	NiTi	Er:YAG	Er,Cr:YSGG	Unprepared
Aberrations	4	3	4	4
Form	2	0	1	1
Apical stop	1	2	1	1
Smoothness	3	0	2	2
Debris	3	0	2	1

Figure 9 A chart of debris score by group.



	NiTi	Er:YAG	Er,Cr:YSGG	Unprepared
Score 3	44	5	17	12
Score 2	23	7	18	15
Score 1	6	22	15	16
Score 0	2	41	19	26

Figure 10 A chart of smoothness score by group.



	NiTi	Er:YAG	Er,Cr:YSGG	Unprepared
Score 3	67	12	20	19
Score 2	7	8	21	21
Score 1	1	14	24	18
Score 0	0	41	4	11

Figure 11 A chart of apical stop score by group.

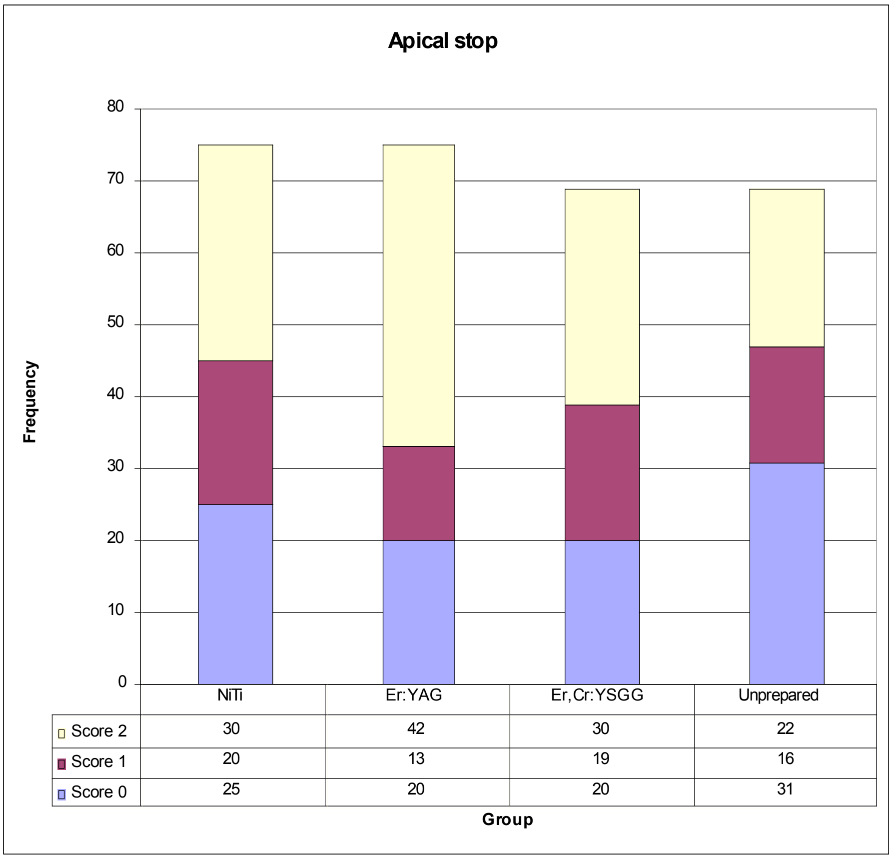


Figure 12 A chart of form score by group.

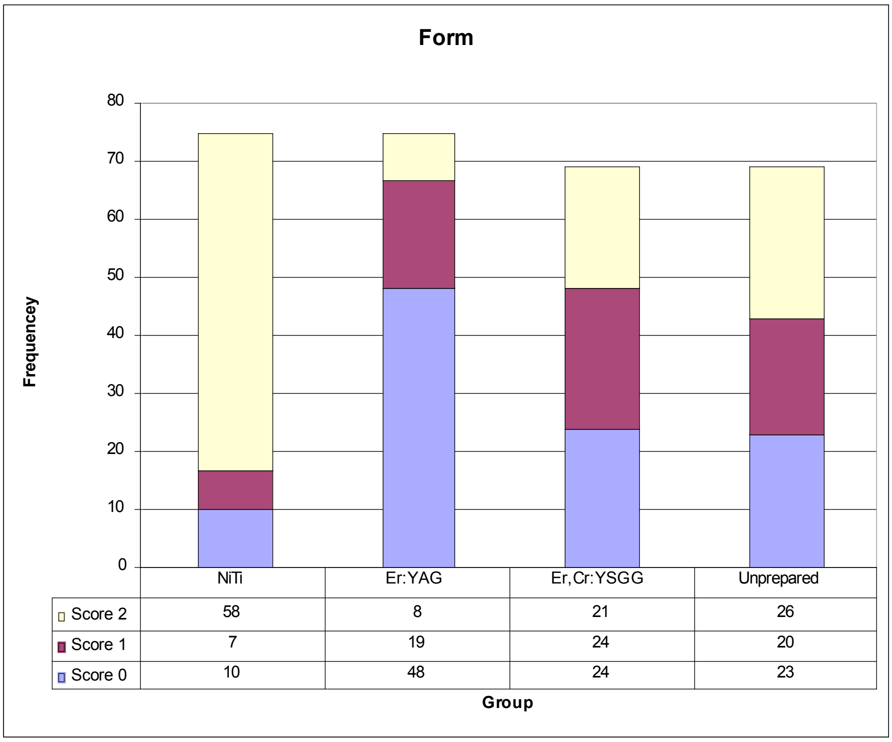
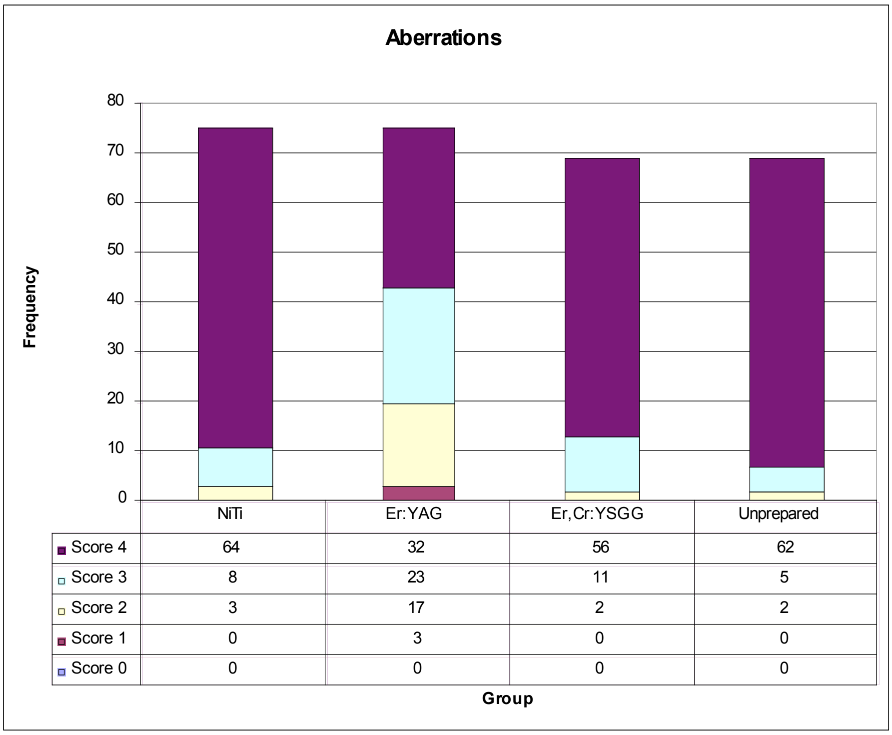


Figure 13 A chart of aberration score by group.



	NiTi	Er:YAG	Er,Cr:YSGG	Unprepared
Score 4	64	32	56	62
Score 3	8	23	11	5
Score 2	3	17	2	2
Score 1	0	3	0	0
Score 0	0	0	0	0

Discussion

Debris removal from the root canal in order to eliminate micro-organisms from the root canal system is a key objective of successful root canal treatment.[3, 4] This study compared the ability of 2 laser root canal preparation techniques with Er:YAG and Er,Cr:YSGG lasers to achieve this objective.

This study demonstrated that debris removal from the root canal could not be consistently removed. The NiTi Group was associated with clean root canal walls or walls that were covered with only very few debris particles ($P<0.05$), most canals were completely clean but some retained debris. This finding is in general agreement with other studies that have

examined the removal of debris by other rotary NiTi and hand file root canal preparation techniques.[44, 51-53]

A recent study [34] investigated the cleaning effectiveness and the shaping ability of K3 nickel-titanium rotary instruments and stainless steel hand K-Flexofiles during the preparation of curved root canals in extracted human teeth. Using a SEM, the investigators found that root canals could not be completely cleaned with either K3 or hand files (Flexofiles), and that more effective cleaning was found in the coronal and middle thirds of canals.

Moreover, this study showed that the Er:YAG and Er,Cr:YSGG techniques did not remove debris from the root canals as well as the positive controls and were not associated with clean canals ($P<0.05$). These findings are in general agreement with similar studies by Matsuoka et al.[12, 30]

Matsuoka et al [12] investigated the effect of Er:YAG laser to remove debris near the apical seats in root canals. The root canals were observed by stereoscopy and scanning electron microscopy and the degree of remaining debris on the apical seats was scored. The investigators were able to conclude that Er:YAG laser irradiation is effective for removal of debris near the apical seats. However, the apical seats were not assessed to be completely clean.

Yet further investigations by Matsuoka et al [30] evaluated morphologically the capability of Er:YAG laser irradiation for root canal preparation in 40 extracted human teeth. Despite preparing the canals to a size 90 K-type

file with 5% NaOCl and 3% H_2O_2 before introduction of the Er:YAG laser, the investigators found that remnant pulp tissue after laser irradiation was observed in some teeth but not recognised in others depending on which parameters were set on the Er:YAG laser. Nevertheless, the investigators suggested that Er:YAG laser irradiation is capable of root canal preparation if appropriate parameters are selected relative to the root canal size.

On the other hand, Yamazaki et al [31] found that debris could be removed with Er,Cr:YSGG laser. Yamazaki et al [31] evaluated the morphological changes in root canal walls as a result of intra-canal irradiation by Er,Cr:YSGG laser under various conditions on 60 extracted single-rooted human teeth. This group of investigators evaluated the root canals by stereoscopy and scanning electron microscopy observed the root canals to be free of debris in the teeth irradiated with cooling. However, the root canals were all instrumented to a size 80 K-type file at the working length with 5% NaOCl and 3% H_2O_2 before introduction of the Er,Cr:YSGG laser. The investigators concluded that Er,Cr:YSGG laser irradiation with water spray cooling is a useful method for removal of debris from root canals.

A point of differentiation between the present study and these similar studies is that they were all instrumented to a large apical preparation size with conventional hand file techniques and irrigated with Sodium hypochlorite and H_2O_2 prior to the introduction of the laser. Whereas the present study either pre-prepared the canals to a size 30 K-type file in the case of the Er,Cr Group or only a size 15 K-type file in the Er:YAG

Group, and during the preparation only saline was used as an irrigation solution. Therefore, any reduction in debris from the root canals was largely due to the mechanical processes of root canal preparation technique employed in each group and not from the prior instrumentation or from the irrigation solutions used.

The Laser protocols in this study did not use sodium hypochlorite and EDTA because it is has been shown that debris were removed using appropriate laser parameters.[7, 8] Furthermore, Er:YAG laser irradiation has been demonstrated to be more effective in removing debris on root canal walls than the Argon, CO_2 or Nd:YAG laser.[9-13] However, lasers have been used after the root canals had already been enlarged to a minimum of a size 40 K-type file and in conjunction with an irrigation solution of sodium hypochlorite, known to effectively dissolve loose organic debris from the root canal.[14-16] Therefore, this study shows that root canal preparation using lasers is not sufficient to remove debris without the use of irrigation solutions to dissolve and flush out debris when compared to the NiTi Group which used sodium hypochlorite and EDTA irrigation solutions.

The removal of debris by lasers is possible, however it is hard to clean all root canal walls, because the laser is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls.[2]

A key objective of this study was to compare the shaping ability of the experimental Er:YAG technique with the manufacturer recommended Er,Cr:YSGG technique. K3 files were chosen for the NiTi Group because it is generally accepted that rotary NiTi files show superior

cutting efficiency and more ideal shape when compared to hand files.[34, 51, 52]

This study demonstrated that the NiTi Group was associated with smooth and regular root canal surfaces; that are well flowing and tapered root canal preparations ($P<0.05$). (Figures 2, and 10-13) Whereas, the experimental Er:YAG Group was associated with well defined apical stops in the root canal preparations but was also associated with the formation of aberrations within the root canal preparations ($P<0.05$). (Figures 3, and 10-13).

The results of the NiTi Group are in general agreement with a similar study by Schafer and Florek [35] who compared the shape, centring ability, and degree of transportation between rotary K3 instruments and hand-filed root canal preparations in curved simulated root canals. The investigators found that K3 instruments achieved better canal geometry and showed significantly less canal transportation in curved simulated root canals than the hand files.

There is little published on the shaping ability of lasers to prepare root canals, specifically Er,Cr:YSGG and Er:YAG in terms of surface smoothness, root canal flow and taper, formation of an apical stop, and the presence of aberrations such as ledges, elbows, and perforations.

However, Yamazaki [31] noted that a rough and irregular root canal surface should be avoided. Surface roughness in the form of carbonization and craters should be avoided because their presence would prevent intimate contact between root canal walls and filled materials. The investigators

recommended that the output powers should be below 3W if debris and smear layer are to be removed from root canal walls while avoiding the production of caters on root canal walls.[31, 54] Yet this study used output powers of 1.5W as recommended by the manufacturer (see appendix as recommended by Chen) and completely smooth surfaces in the Er,Cr Group could not be consistently achieved.

This study found that the Er:YAG Group was associated with well defined apical stops ($P<0.05$). These findings were in agreement with Matsuoka et al,[30] who evaluated morphologically the capability of Er:YAG laser irradiation for root canal preparation in vitro. Matsuoka et al [30] assessed the root canal surfaces by SEM and found that in irradiated areas the surface was rough and irregular, and that an apical stop could be formed. Matsuoka et al [30] concluded that Er:YAG laser irradiation is capable of root canal preparation. However, when the observations of this study are also considered, root canals prepared by Er:YAG laser should only be obturated by a thermo-plasticised gutta-percha or a technique that allowed the root filling of the rough and irregular surface.

Furthermore, the Er:YAG Group was associated with the formation of aberrations within the root canals ($P<0.05$). The aberrations observed included apical zip, elbows, ledges and perforations. (Figures 5, 6, 13 and 18) The development of aberrations in Er:YAG root canal preparations has also been observed by Masuoka et al,[30] who found perforations to occur in 20-30% of their preparations performed in vitro. Masuoka et al [30] thought that perforation was caused by the incorrect

direction of laser beam due to blind sight in root canals. This becomes even more serious in curved root canals.

However, this study's findings were in disagreement with Kesler et al, [33] who recently conducted a study of 28 single-rooted extracted central incisors teeth with straight roots to demonstrate the effectiveness of Er:YAG laser to clean and shape the root canal. Kesler et al designed a comparative study of 2 different Er:YAG lasers and conventional K-type file preparation of root canals that were evaluated by histological and SEM evaluation. The investigators concluded that the Er:YAG lasers are effective in shaping, cleaning, and enlarging straight root canals faster and more efficiently then traditional methods. However, the conclusions drawn by Kesler et al must be considered with caution because only a small part of the sample was semi-quantitatively analysed (i.e. 2 teeth per group, total 8), the results of the control groups were combined and then compared to the individual test groups, and finally, inappropriate statistical methods were used.

The overall (total) score of the assessment criteria clearly demonstrates the differences between the experimental and control groups of this study. The study design appears to be valid since there is significant difference between the NiTi Group and the Unprepared Group. Similar assessment criteria have been used in previous studies to assess conventional root canal preparation techniques (Table 3).

Thus, the overall score gives a balanced view of the ability of the Er:YAG and Er,Cr:YSGG lasers to prepare root canals within straight

root canals. The Er:YAG Group root canals were not as well prepared as those in the other groups.

There was no significant difference found between the overall score of the Er,Cr Group and the Unprepared Group (P= 0.181013). A power analysis found that under the conditions of this study each group would need to have included 174 teeth, a total of 696 study teeth to achieve a statistical power of 80% to detect a difference between the 4 groups with an overall significance level of 0.05 by multiple Mann-Whitney U Tests.[50]

The reliability of the study design was tested and assessed by the Kappa reliability test and Spearman rank correlation that were used to assess inter-evaluator agreement and intra-evaluator reliability. There was fair agreement between evaluators and good agreement between the results when the evaluators repeated the assessment a week later, which reflects the subjective and ordinal nature of the assessment criteria.

This is an in vitro study that has been deliberately limited to a sample of single roots with straight and uncomplicated root canal systems that have standardised straight line access to the root canal. Nevertheless, these limitations to the sample allowed the direct comparison of 2 laser root canal preparation techniques. The results of this study demonstrate that more research and development is required to show significant advantages of lasers over current conventional and modern root canal preparation techniques before lasers can be used successfully in vivo.

The laser beam is thought to have the ability to remove debris and produce a tapered root canal preparation [2, 12, 17] but it is hard to lase canal walls because the laser is emitted straight ahead, making it almost impossible to lase the lateral canal walls.

This study and the work of others suggests that it is necessary to improve the fibre tip and the method in order to irradiate all areas of root canal walls.[2, 12, 31, 55-57] The recent development of thinner laser tips (Er,Cr:YSGG fibres as little as 200µm, and Er:YAG fibres from 285µm), which have not been used in similar previous studies has allowed the laser to be used more effectively within root canals, without the necessity for excessive enlargement of the root canal. However, this study demonstrates that it is not enough to have a thin flexible laser fibre, a laser tip that can irradiate the lateral canal walls is also necessary. Such as a laser tip that provides an annular cutting configuration of the laser energy beam.[12] Yamazaki et al [31] noted that the tip geometry may be more important than thickness of the fibre allowing the laser fibre to cut sideways and follow the curves of the root canal and avoid the formation of unnecessary root canal preparation aberrations such as ledges and zips.

Recently, Stabholz [55] demonstrated the potential of a newly developed side firing laser tip, the RCLase Side-firing Spiral Tip in an SEM study of 20 extracted human teeth. The investigators observed that by using the Er:YAG laser irradiation with the RCLase Side-firing Spiral Tip the root canal system can be efficiently cleaned. However, this tip was designed for the cleansing of root canals following their bio-mechanical

preparation with NiTi rotary files and not to prepare root canals with laser irradiation alone as in this study.

In this study, the objectives of Er:YAG experimental root canal preparation technique were not met. For instance, the experimental technique could not consistently prepare the canals without causing deviation or zipping of the root canal. Furthermore, despite early coronal flaring, apical extrusion of debris being exploded through the apex was observed with the experimental set up used.

The Er:YAG root canal preparation is characterised by rough and irregular root canal walls, containing abrupt changes in direction and ledges, the root canals were often hour glass or cylindrical in shape, debris could not be completely removed and aberrations (such as ledges and elbows) were often associated with this technique. Possible reasons for the poor preparation of the root canals may be due to tip design and end cutting nature of the fibres, or too high pulse energy causing dentin too cut too efficiently.

The main advantages of the experimental Er:YAG technique include: early access for irrigation solutions; early removal of cervical dentine interferences and reduction of canal curvatures promoting tactile awareness in apical third of the canal; straight line access is developed; early flaring reduces the potential of debris fragments being blasted through the apex; and micro-organisms and necrotic pulp are removed in the initial phase of root canal preparation, and decreasing the probability of carrying them to the apex and producing an exacerbation of apical periodontitis.

Nevertheless, the significant disadvantages of the experimental Er:YAG technique include: this technique is only indicated for straight root canals or in the straight portions of curved canals; and there is a risk of over-instrumentation. Note the use of hand files in the Er:YAG Group was still necessary to scout the root canal for aberrant anatomy or blockages prior to the introduction of the laser fibre tips.

Therefore, the experimental Er:YAG root canal preparation technique does not have any significant advantages over more conventional root canal preparation techniques and the disadvantages do not support the use of this experimental technique without further development of laser fibre tip design. For example, this experimental Er:YAG technique should be evaluated for debris and smear layer removal from the prepared root canal surface.[58]

Conclusions

The NiTi Group was associated with clinically clean, smooth and regular root canal surfaces; that are well flowing and tapered root canal preparations ($P<0.05$). Overall, the NiTi Group was significantly superior to the other groups.

The Er:YAG Group was associated with well defined apical stops in the root canal preparations but was also associated with the formation of aberrations within the root canal preparations ($P<0.05$). Moreover, the Er:YAG Group proved to be significantly inferior to the other groups.

A difference in the overall evaluation criteria could not be detected between the Er,Cr Group and the Unprepared Group. This difference

was small and under the conditions of this study each group would need to have included 174 teeth, a total of 696 study teeth to achieve a statistical power of 80% to detect a difference between the 4 groups with an overall significance level of 0.05.

Therefore, the laser root canal preparation techniques with either the Er:YAG laser using an experimental root canal preparation technique or the Er,Cr:YSGG laser cannot be supported when compared to more popular root canal preparation techniques such as NiTi rotary instruments.

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Paper 2

Title

An evaluation of root canal preparation comparing Er:YAG and Er,Cr:YSGG laser: Part 2 (scanning electron microscopy)

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Abstract

Background: Laser root canal preparation techniques are mainly experimental. However, the US FDA recently approved Er,Cr:YSGG laser for clinical use in preparing root canals. The aim of this study was to compare root canal debris and smear layer removal when Er:YAG and Er,Cr:YSGG laser root canal preparation techniques were used.

Methods: 32 extracted human single rooted teeth were randomly allocated to 4 groups: the NiTi Group prepared by rotary NiTi; the Er:YAG Group prepared by Er:YAG laser; the Er,Cr Group prepared by Er,Cr:YSGG laser; and the Unprepared Group. Teeth were bisected, evaluated by SEM, and scored according to predefined criteria. Data were analysed by the Kruskal-Wallis Test and the Mann-Whitney U Test.

Results: Overall, the NiTi and Er:YAG Groups were superior to the Unprepared Group ($P<0.05$); the NiTi Group was not different from the Er:YAG Group ($P>0.05$); and the Er,Cr Group was not different from the Unprepared Groups ($P>0.05$). The sample size would need to be at least 100 teeth if the study were to have sufficient power to detect a significant difference between the NiTi and Er,Cr Groups.

Conclusions: Debris and smear layer removal by Er:YAG laser during root canal preparation was comparable to rotary instruments. Whereas, the Er,Cr:YSGG laser was not comparable to rotary instruments.

Introduction

Guidelines from peak endodontic bodies state that the primary objectives of root canal instrumentation are the elimination of the residual pulp tissue, the removal of debris and the maintenance of the original canal curvature during enlargement.[1, 2]

Moreover, smear layer is formed on the root canal wall after the direct action of endodontic filing on the wall.[3, 4] The smear layer consists of ground dentine and predentine, pulpal remnants, odontoblast processes, and bacteria.[3, 4] It is controversial whether the smear layer provides a beneficial or detrimental affect and whether or not it should be removed from the canal walls. The benefits of smear layer retention may be a reduction in the permeability of dentin, acting as a barrier to bacterial metabolites, preventing the bacterial invasion of the dentine tubules.[5, 6] However, the deleterious effects of smear layer retention may include the harbouring [6, 7] of bacteria, and prevention of irrigation solution, medicaments,[6-8] and sealer from penetrating into the dentinal tubules, and from contacting the root canal wall.[9, 10] Therefore, the benefits of smear layer removal appear to outweigh the benefits of smear layer retention and smear layer removal is also a common goal of root canal preparation.

Endodontic applications of various lasers are becoming increasingly popular in endodontics. Numerous investigations of lasers in endodontics have dealt with pulpal extirpation, shaping of root canals, apical sealing and laser apicoectomy sealing. [11, 12]

A variety of lasers have been developed and applied in dentistry, they include: semiconductor diode, carbon dioxide (CO_2), helium-neon (HeNe), neodymium:yttrium-aluminium-garnet (Nd:YAG), argon, erbium (Er:YAG), and erbium, chromium (Er,Cr:YSGG).[11]

Smear layer and debris can be removed from root canals when appropriate laser wavelengths and operating parameters are used.[13, 14] Furthermore, Er:YAG laser irradiation has been demonstrated to be more effective in removing debris on root canal walls than the Argon, CO_2 or Nd:YAG laser.[15-19] However, lasers have only been used after the root canals had already been enlarged to a minimum of a size 40 K-type file and in conjunction with an irrigation solution of sodium hypochlorite, known to effectively dissolve loose organic debris from the root canal.[8, 20, 21]

Some pulsed laser devices produce cavitation effects in root canals in a manner similar to that of the ultrasonic irrigator.[19, 22] At present, the effect is weaker than that of ultrasonic irrigation; this laser technique is likely to be improved in the future. Straight and slightly curved root canals as well as wider root canals are indications for this treatment. The pulsed Nd:YAG laser, Er:YAG laser, and ErCr:YSGG laser are recommended, but the laser fibre still requires slight improvement.[11]

Lasers, such as CO_2 and Nd:YAG surgical lasers, have a well recognized destructive effect on bacteria, and this has led to the development of techniques for sterilising wounds, carious lesions and root canals.[23, 24] Others, have shown the beneficial effects of laser treatment in disinfecting root canals.[24-26] Whereas, conventional endodontic

treatment is not fully effective due to microbial colonization of root canal walls.[27, 28] Thus, when appropriate laser wavelengths and operating parameters are used there is the possibility of one-step disinfection, including of anaerobic micro-organisms.

Therefore, when the numerous attributes of lasers in endodontics are taken in combination, there is a potential for using lasers to prepare root canals through shaping, cleaning, debris removal, smear layer removal and sterilisation of the root canal with one instrumentation sequence. There is potential to reduce or eliminate the need for special irrigation solutions, intra-canal medicaments and complicated instrumentation methods.

Previous studies have shown the potential that lasers can be used to effectively remove smear layer from root canal walls.[13, 15-17, 29] Er:YAG laser is effective in removing debris and smear layer from root canal walls.[16, 19, 30]

In 1992, Levy [22] described a technique to prepare root canals with an Nd:YAG laser and compared these preparations to a conventional hand-file technique. Levy observed the potential for a laser beam to prepare a tapered root canal preparation and to remove debris.

However, Cohen et al [31] were the first to describe in detail, an endodontic laser technique to prepare a root canal using a Ho:YAG laser. They suggested:

1. Scouting the canal with a size 15 K-type file.

2. 'Step back' with the laser fiberoptic guide starting at 140µm fibre, then a 245µm fibre, then a 355µm fibre and finally a 410µm fibre. The fibres will be inserted to the apex, energised and then withdrawn slowly at about 4mm/sec.

3. The active cutting laser energy was directed away from the long axis of the fiberoptic guide in the shape of an annular ring. In this configuration, there was no cutting energy in the centre of the ring. In affect, the lateral walls of the canal will be lased, not the apical area. This lasing configuration was accomplished using a proprietary optical setup in the laser itself.

The laser root canal preparation technique described by Cohen et al [31] is an apical-coronal root canal preparation technique with many of the disadvantages of such a technique, such as: lack of early coronal access results in greater potential for debris extrusion; less access for irrigants to apical areas early in preparation; poor tactile discrimination at apex due to coronal binding of files; and poor early straight line access to the apex. Therefore, one of the objectives of this study was to prepare root canals using Er:YAG laser with an experimental coronal-apical root canal preparation technique and avoiding many of the limitations of an apical-coronal root canal preparation technique.

Er,Cr laser has recently been approved by the US FDA for use in endodontics and is being promoted as suitable for preparing root canals.[32-35] The root canal preparation technique with this laser is an apical-coronal technique similar to the technique described by Cohen et al. [31] However, this technique does not purely rely on the laser to

prepare the root canals and is in reality a hybrid technique that relies largely on the use of conventional root canal preparation techniques such as hand files to prepare the apical seat of the root canal preparation and then uses laser to shape the root canal.

Erbium is a metallic element of the rare-earth group that occurs with yttrium and is also used as a source of laser irradiation. An Er:YAG laser (Key Laser®, KEY Laser 1242, KaVo Dental GmbH, Jena Germany) is a solid state, pulsed laser that has a maximum emission in the mid-infrared region at 2.94µm. Water absorbs strongly in this region. The pulse energy of this unit can vary from 20mJ/pulse to 600mJ/pulse and the power output can be up to 6W. The laser is delivered through fiberoptic tips that have terminal diameters of 285, 375 or 470µm.

Whereas, the Er,Cr:YSGG laser (Millennium system, Biolase Technology, Inc; San Clemente, California) uses a pulsed laser energy source delivered through a sapphire tip that is bathed by an air/water spray. It operates at a wavelength of 2.78µm and the power output can be up to 6.0W. The laser is delivered through fiberoptic tips that have a terminal diameter of 200, 320, 400 or 800µm. The fiberoptic tips are bathed in an adjustable air/water spray. This device generates precise hard tissue cuts by virtue of laser energy interaction with water above and at the tissue interface, and it has therefore been termed a hydrokinetic system (HKS).[36]

A number of recent studies are similar to the proposed study.[15-19, 29-31, 37-39] However, none of these studies have compared the use of different

lasers such as Er:YAG and Er,Cr:YSGG to prepare root canals, and none have been compared with currently accepted root canal preparation techniques such as rotary NiTi instruments.[40, 41]

The aim of this study was to investigate root canal morphology after laser treatment using newly developed fibre optic endodontic handpieces with flexible and thinner laser fibres.

Therefore, this study tested the hypothesis that root canals prepared with either Er:YAG laser or Er,Cr:YSGG laser were as good as more popular root canal preparation techniques (NiTi rotary instruments); in terms of debris removal and smear layer removal, as assessed by scanning electron microscopy.

Material and methods

160 extracted human teeth were randomly drawn from a well mixed collection of extracted teeth single-rooted from the Supervisor's laboratory stock that were stored in Brisbane tap water. The teeth were drawn by an independent person who was blinded to the study's objectives. The teeth were thoroughly mixed in the "barrel" in between each draw.

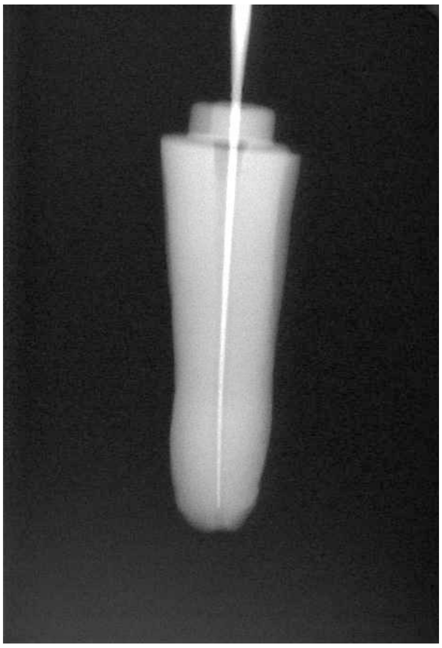
The teeth were extracted because they were badly decayed and unrestorable or for periodontal reasons. Therefore, the teeth were decoronated to standardise coronal access preparations. A size 10 K-type file was introduced into the canal until it appeared at the apical foramen to assess for inclusion into the study. The working length was established by subtracting 1mm from this length.

Teeth were further assessed for inclusion into the study by digital radiographic screening (Sirona Heliodent DS, D3334 and D3302, Sirona Dental Systems GmbH, Bensheim, Germany; and Sidexis Next Generation V 1.2, Sirona Dental Systems GmbH, Germany). The screening radiographic examination involved taking two periapical radiographs, one from the buccolingual view and one from the mesiodistal view (Figure 14).

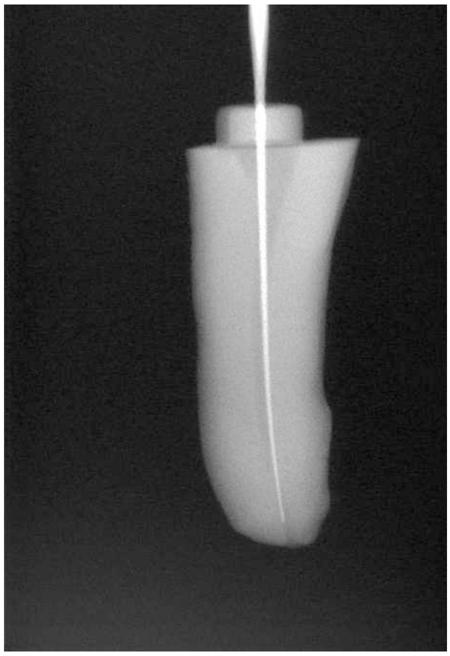
Teeth were finally excluded if they did not have a single patent canal; simple root canal anatomy; uncomplicated apical anatomy; only a single mild root canal curvature; and suitable working length.

Figure 14. Representative digital periapical radiographs of a specimen allocated to the NiTi Group, the buccolingual view is seen in a) and the mesiodistal view is seen in b)

a)



b)



58 teeth did not meet the study inclusion criteria and were excluded from the study (Figure 19). In summary, the teeth were excluded for the following reasons:

1. previously undetected root canal fillings (n=8);

2. multiple root canals were present (n=22);
3. root canals were blocked (n=1);
4. unusual root canal anatomy (n=1);
5. evidence of apical resorption (n=2);
6. acute apical root canal curvature (n=4);
7. prominent and extensive apical deltas were present (n=2);
8. s-shape root canal was present (n=2);
9. there was evidence of incomplete root formation (n=1);
10. unusual apical root canal anatomy (n=1); and
11. extreme working length (i.e. W/L<11mm, W/L>17mm) (n=16).

Estimated data were analysed using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA) to determine that group sample sizes of 15 and 15 achieve 80% power to detect a difference of 3.8 between the null hypothesis that both group means are 24.0 and the alternative hypothesis that the mean of group 2 is 20.2 with known group standard deviations of 3.0 and 3.0 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

The significance level of 0.0083 was used because the desired significance level for the study was 0.05. Accordingly, to compensate for multiple comparisons between the means of 4 independent groups, this significance level was reduced from 0.05 to 0.0083.

In other words, based on 0.8 power to detect a significant difference (P=0.0083, two-sided) 15 effective specimens were be required for each study group. However, each specimen was evaluated by 3 different evaluators creating an actual group sample size of 5 teeth.

Furthermore, to compensate for excluded teeth, 7 teeth (28 teeth in total) in each group were required.

All teeth had an equal probability of assignment to the groups and were randomly allocated to 4 groups. A computer random number generator was used to generate a random number from 1 to 4 and the teeth were then allocated to each group in sequence until all had been allocated to the 4 groups. Thus, those teeth of varying levels of root complexity were distributed evenly amongst the four groups.

The teeth were allocated to 4 groups:

1. NiTi Group, prepared with rotary NiTi files and used as positive controls;
2. Er:YAG Group, prepared with Er:YAG laser root canal preparation techniques;
3. Er,Cr:YSGG Group, prepared with Er,Cr:YSGG laser root canal preparation techniques; and
4. Unprepared Group, were left unprepared and used as negative controls.

Interventions

The following interventions were implemented on the different study groups.

Er,Cr:YSGG Group

Er,Cr:YSGG laser (Waterlase™, Millennium, Biolase Technology Inc, San Clemente, CA, USA) was used as recommended by the manufacturer.[32-35, 42]

In summary, the root canal preparation technique [32, 33, 42] was:

1. Glide path establishment: a glide path was established and the apex was enlarged to at least a size25 K-type file.
2. Root canal debridement: a Z2 (200µm) fibre tip was used 1-2mm short of WL (allow for optimum ablation distance); the tip was aimed at the side of the root canal; the tip was placed, activated and ablation occurred as the tip was withdrawn over 8sec; as the tip is withdrawn a sweeping motion was used; the tip was replaced into the canal and aimed at a different part of the root canal ready for another pass; a total of 6 ablation passes were made, simulating a circumferential filing concept.
3. Root canal shaping: a Z3 (320µm) fibre tip was used as in 2, above; followed by a Z4 (400µm) fibre tip that was used as in 2, above; the root canal was enlarged until a size 35 K-type file fitted easily to working length.
4. Saline irrigation was used in copious quantities.

The parameters used with the Er,Cr:YSGG laser throughout the study have been tabulated (Table 5).

Table 5 Er,Cr:YSGG laser parameters

Procedure	Tip	Power (W)	Water (%)	Air (%)
root canal debridement	Z2 (200µm)	1.5 (<2.5)	24	34
root canal shaping	Z3 (320µm)	1.5 (<2.5)	24	34
root canal shaping	Z4 (400µm)	1.5 (<2.5)	24	34

Er:YAG Group

The Er:YAG laser (Key Laser® (KEY Laser 1242, KaVo Dental GmbH, Jena Germany) was used in an experimental technique developed by the authors.

This experimental technique was developed for this study to discover if a coronal-apical root canal preparation technique could be used successfully in vitro. This experimental technique was based on the following previously described techniques: the crown-down pressureless technique;[43] the balanced force technique;[44] and the double flared technique.[45]

The objectives of this coronal-apical technique were to: produce early coronal flaring with special emphasis on reducing apical extrusion of debris; and to facilitate preparation of curved canals without causing deviation or zipping. Moreover, the prepared surface of the root canal preparation should not be contaminated with debris or smear layer.

In summary, the experimental Er:YAG laser root canal preparation technique was:

1. Scout the coronal 2/3s of the canal with hand files.[46, 47]

   Determine radicular access length to a depth to which a size 30 K-type file penetrates to its point of first resistance. The coronal portion of the canal should be prepared to this length.

2. Pre-enlargement of the coronal 2/3s:[46, 47] straight line access was established with a 50/10 fibre tip; and radicular access preparation by using a #1 band fibre tip, followed by a #2 and then #3 band fibre tip, taken to the radicular access length without any apical force.

3. Scout the apical 1/3 of the canal and verify the glide path with hand files:[46, 47]

   a. Place a size 30 K-type file into the canal until it encounters resistance. Use balanced force technique. Repeat, using a 25 K-type file and then successively smaller files until the working length is reached.

   b. This completes the first instrumentation sequence, which began with a size 30 K-type file at the radicular access length and finish with the largest file that passively reached the working length.

   c. A second instrumentation sequence began with a file one size larger than the file that began the previous sequence (i.e. a size 35 K-type file). This was used with balanced force technique and successively smaller files inserted and similarly rotated until the working length was reached.

The file at the apical seat should be a size larger than in the first sequence.

d. Further sequences of instrumentation were performed until the apical file was a minimum of a size 30 K-type file.

4. Finish the apical 1/3 preparation,[46, 47] the #1, #2 and #3 band fibre tips were used. The root canals were finished with a 0.10 taper as suggested in balanced force technique [44] by stepping back with 1mm increments between successively larger fibre tips. Preparation of the apical third of the canal to the appropriate size using the step-back technique means that much less filing is necessary to establish the final taper. Once again, the use of recapitulation is stressed.[45]
5. The diameter of the foremen was gauged to confirm completion of canal preparation.[46, 47] The apical 1/3 preparation was refined as indicated, (#2 and #3 band fibre tips if indicated).
6. Copious irrigation with saline was used throughout the procedure.

The parameters used with the Er:YAG laser throughout the study have been tabulated (Table 6). The Er:YAG laser was used with a Key Laser® 3 endodontic handpiece 2062 and the parameters used were based on the manufacturer recommendations for settings to cut dentine during restorative procedures.

Table 6 Er:YAG laser parameters

Fibre insert	Diameter (mm)	Length (mm)	Energy (mJ)	Frequency (Hz)	Air	Water
#1 band, 30/28	0.285	28	500	4	Y	N
#2 band, 40/28	0.375	28	450	4	Y	N
#3 band, 50/28	0.470	28	450	4	Y	N
#3 band, 50/10	0.470	10	500	4	Y	N

NiTi Group

Rotary K3 files (SybronEndo, West Collins, CA, USA) were used with a 4:1 reduction handpiece (WE-66 EM, W&H, Buermoos, Austria) powered by a torque-limited electric motor (Endo IT motor, VDW, Munich, Germany). For each file, the torque and speed programmed in the file library of the Endo IT motor were used. The K3 files were used following the crown down technique (variable taper variable tip size) recommended by the manufacturer. In summary, the rotary NiTi root canal preparation technique was to:

1. Confirm coronal patency
2. Determine apical size by using a radiograph and information from step1, estimate final apical size and taper.
3. Begin crown down with a file 3 sizes larger than the intended final apical size.
4. Establish working length after reaching the middle third of the root canal.
5. Complete crown down preparation taking each instrument to resistance. Use each instrument at 300-350rpm for only 5-7 seconds.

6. Copious irrigation with 1% sodium hypochlorite and 17% EDTAC between the introduction of files.[48]

Unprepared Group

The negative control specimens were not instrumented or irrigated except during the initial tooth preparation and assessment for inclusion phase of the study.

After the completion of study interventions, the roots were allowed to air dry.

The roots were bisected into halves by cutting two parallel grooves with a slow-speed carborundum disk on the outer surface of the roots and split with an instrument used as a chisel to prevent contamination of the canals during the separation process.[49] The roots were fractured so that in a longitudinal direction the main root canal curvature was bisected in one plane. The residual loosely bound pulp tissue was removed by using a blast of air. Thus, the walls of the canals were not touched by instruments or irrigating solutions except as described above.

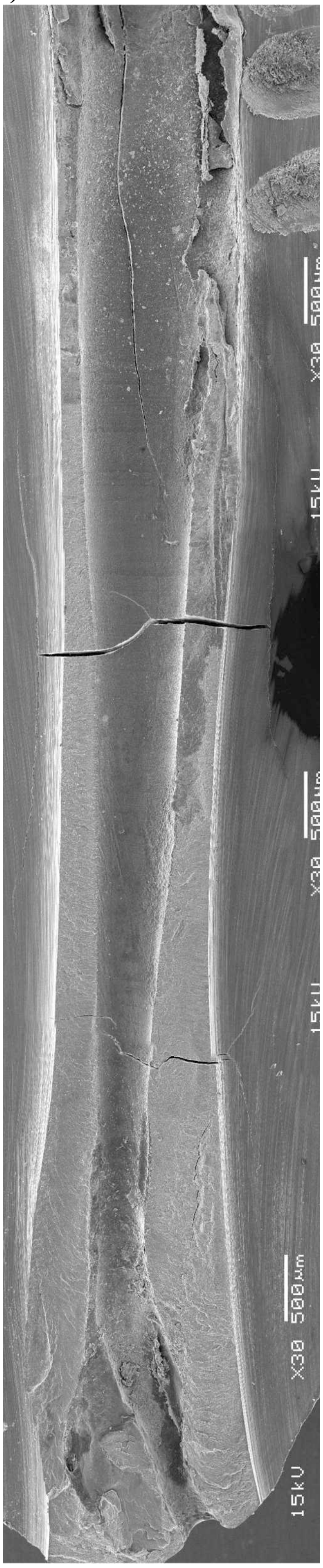
An additional 6 teeth were excluded from the study. Five teeth were excluded because of root fracture during preparation for photomicrographs and one tooth was excluded because of the presence of previously undiagnosed complex root canal anatomy.

The root half showing the major portion of the canal was chosen for examination by SEM, at a magnification of 200 and 1000 times (Figures 15-18).

The sample teeth were a part of a previous unpublished study [50] and were randomly selected from the 4 groups prior to analysis. Additionally, 4 teeth were excluded from the study because of root surface contamination by a fungal over growth obscuring the root surface so badly that an objective evaluation could not be made.

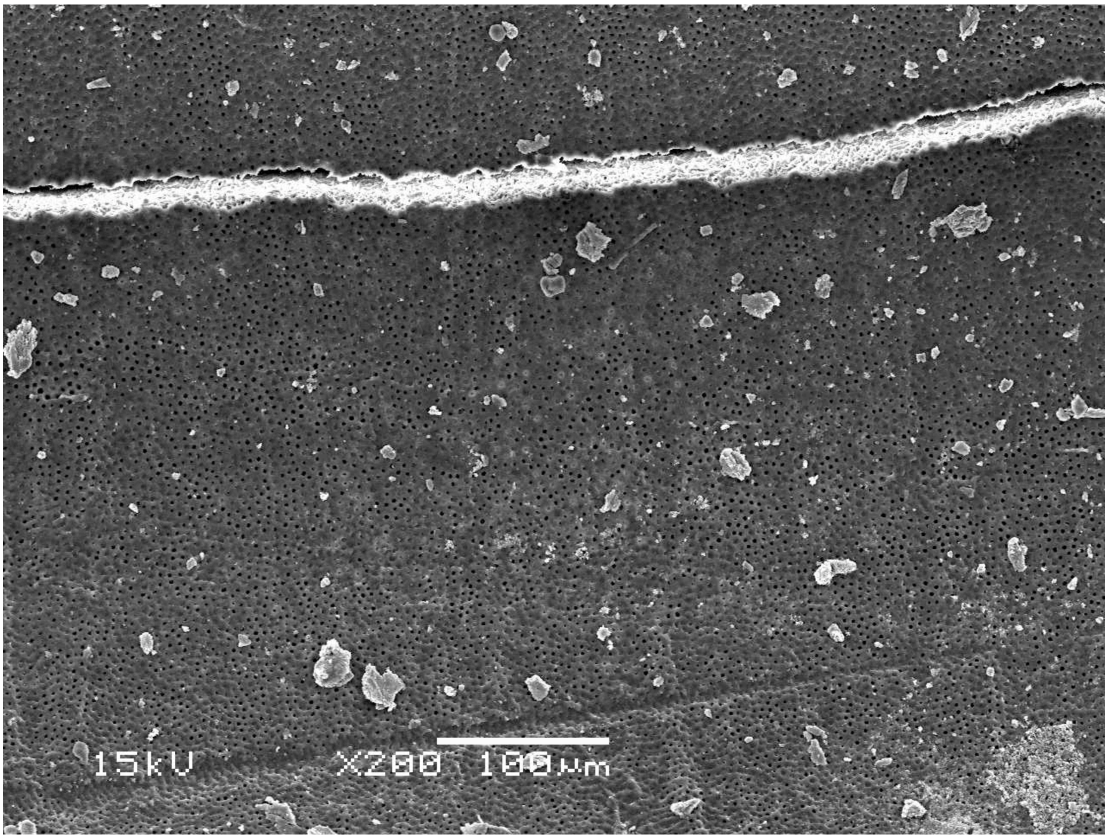
Figure 15 Photomicrographs record the SEM image of a representative tooth from the NiTi Group ; a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

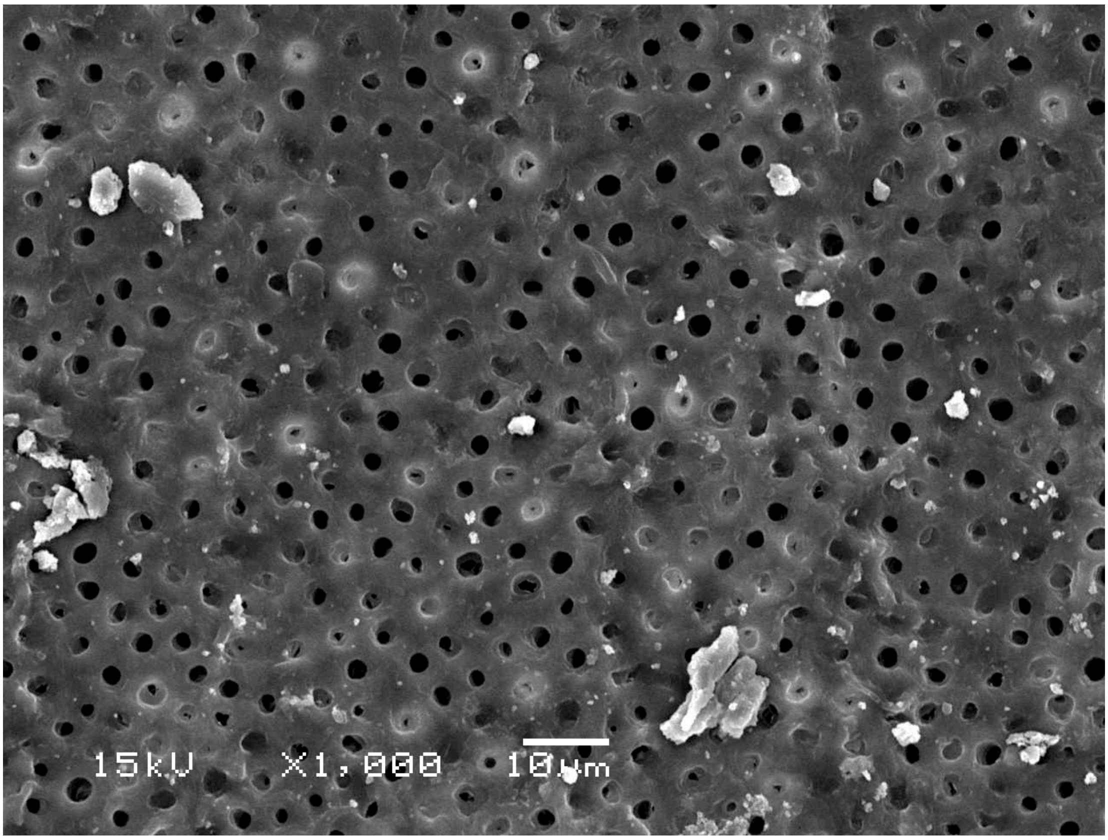


Coronal third

b)

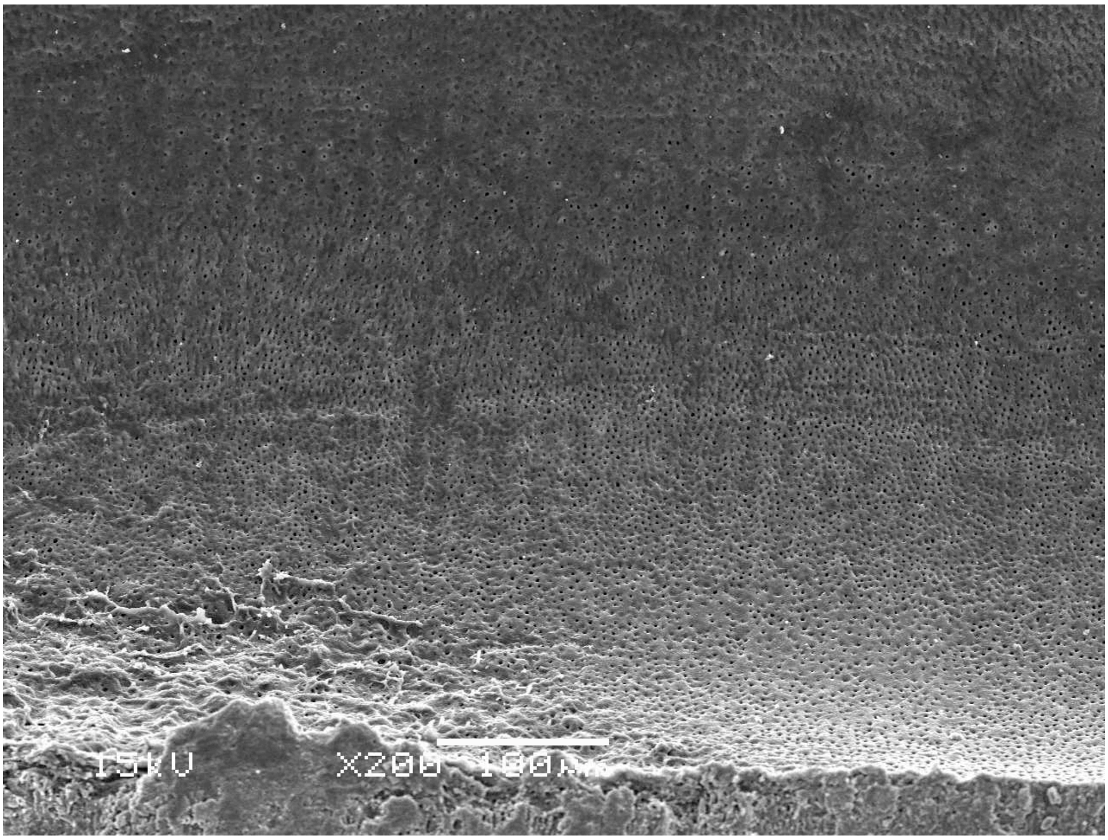


c)

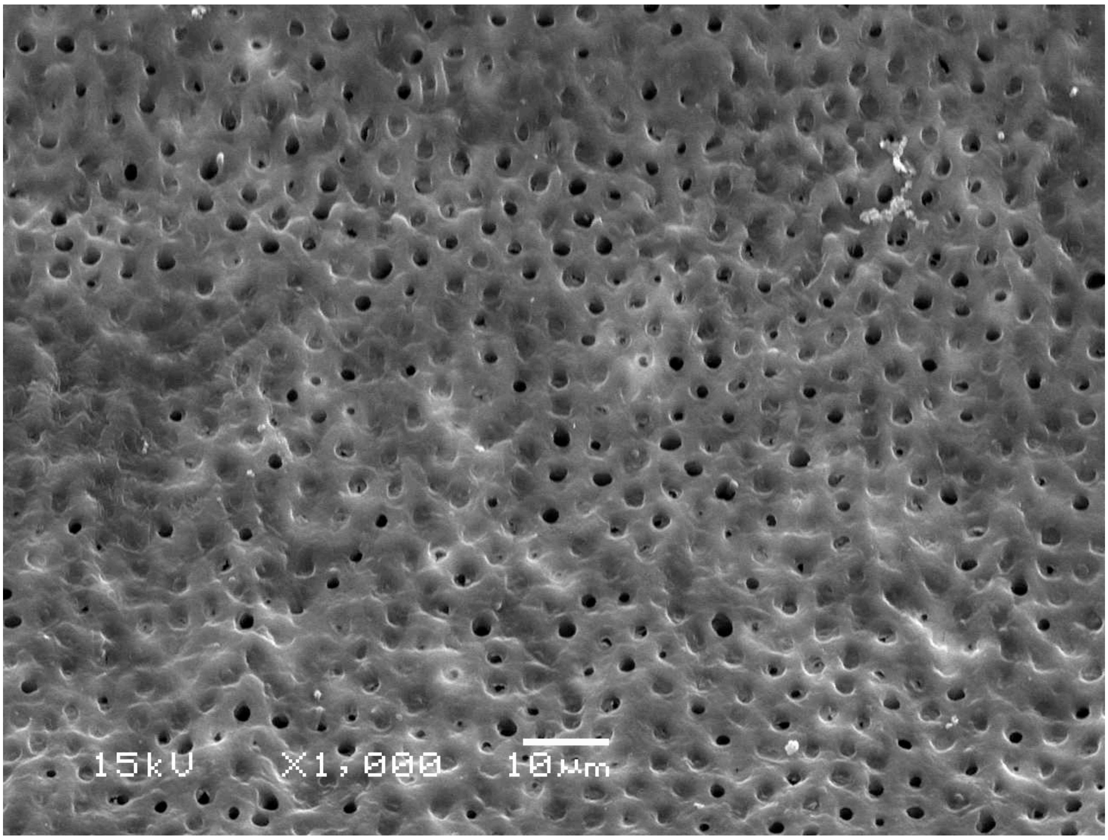


Mid third

d)

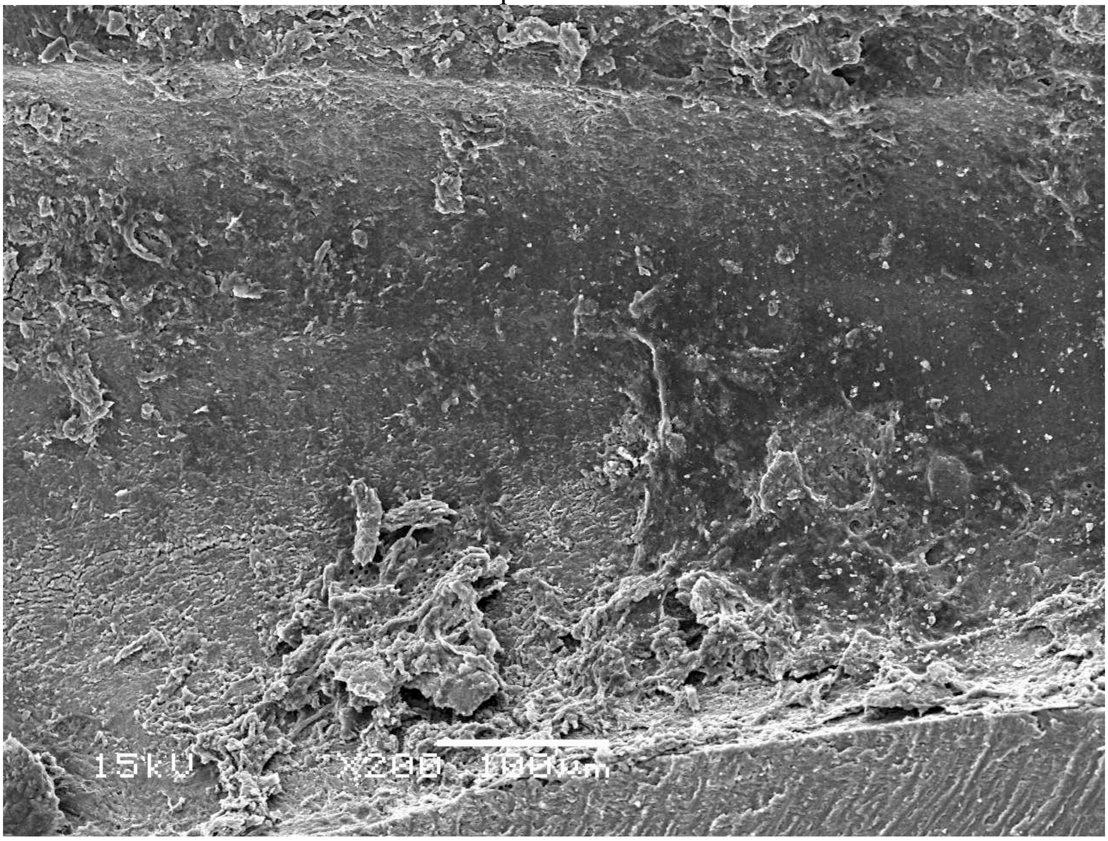


e)



Apical third

f)



g)

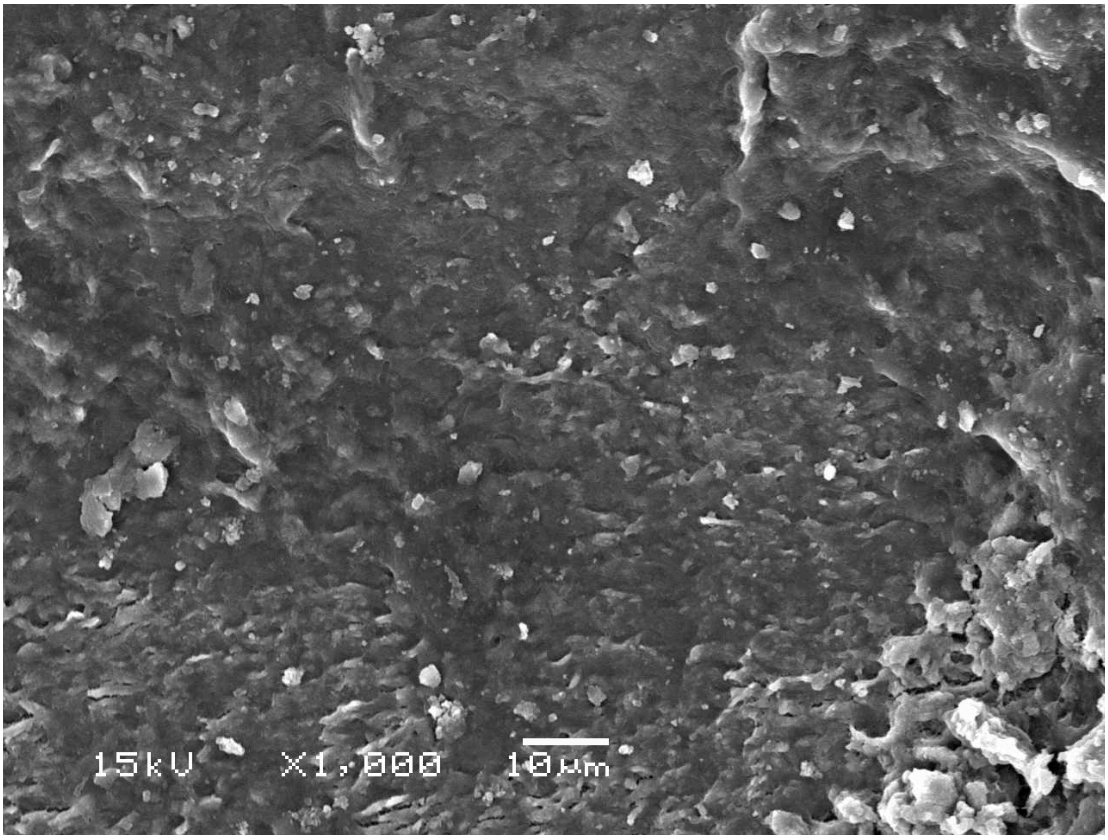
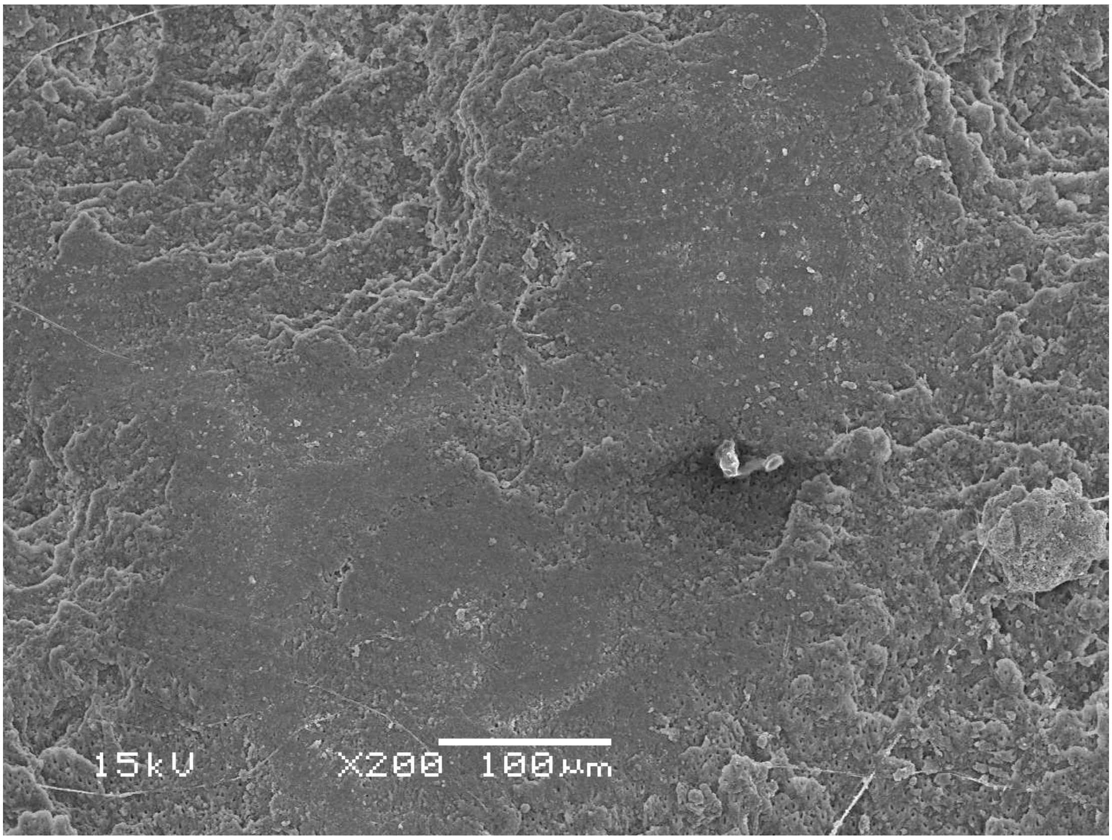


Figure 16 Photomicrographs record the SEM image of a representative tooth from the Er:YAG Group ; a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

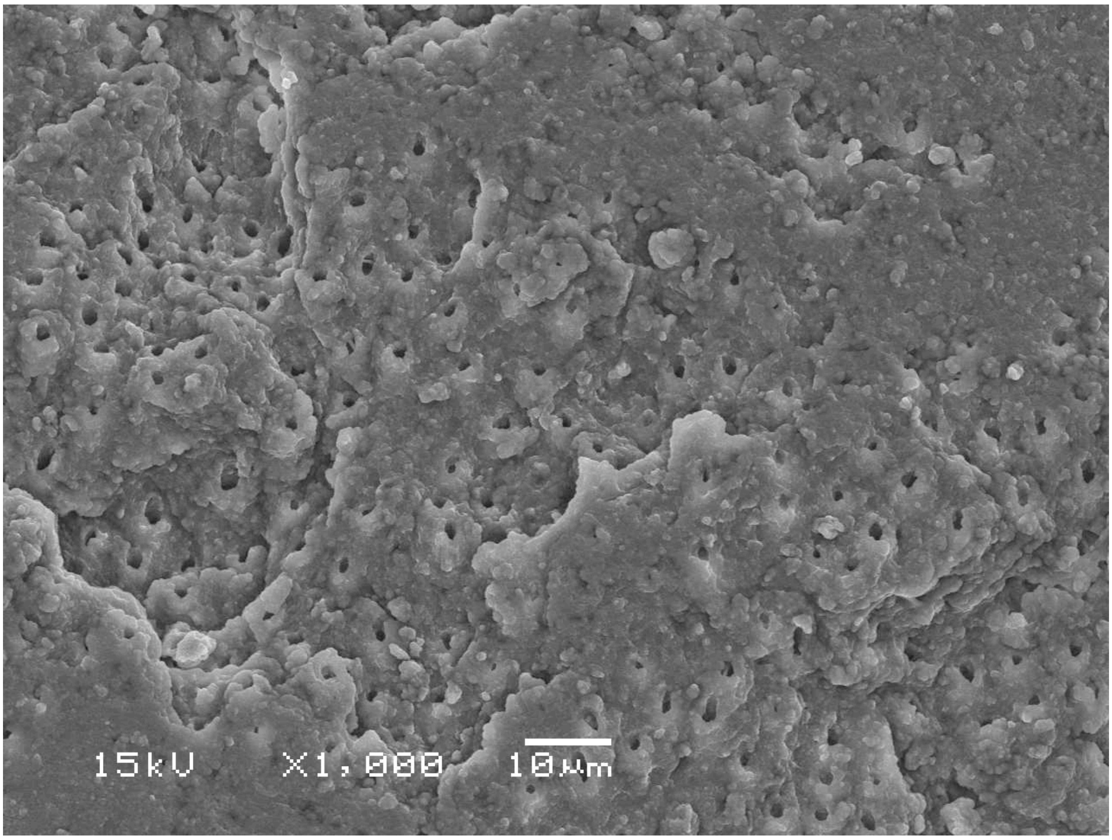
a)

Coronal third

b)

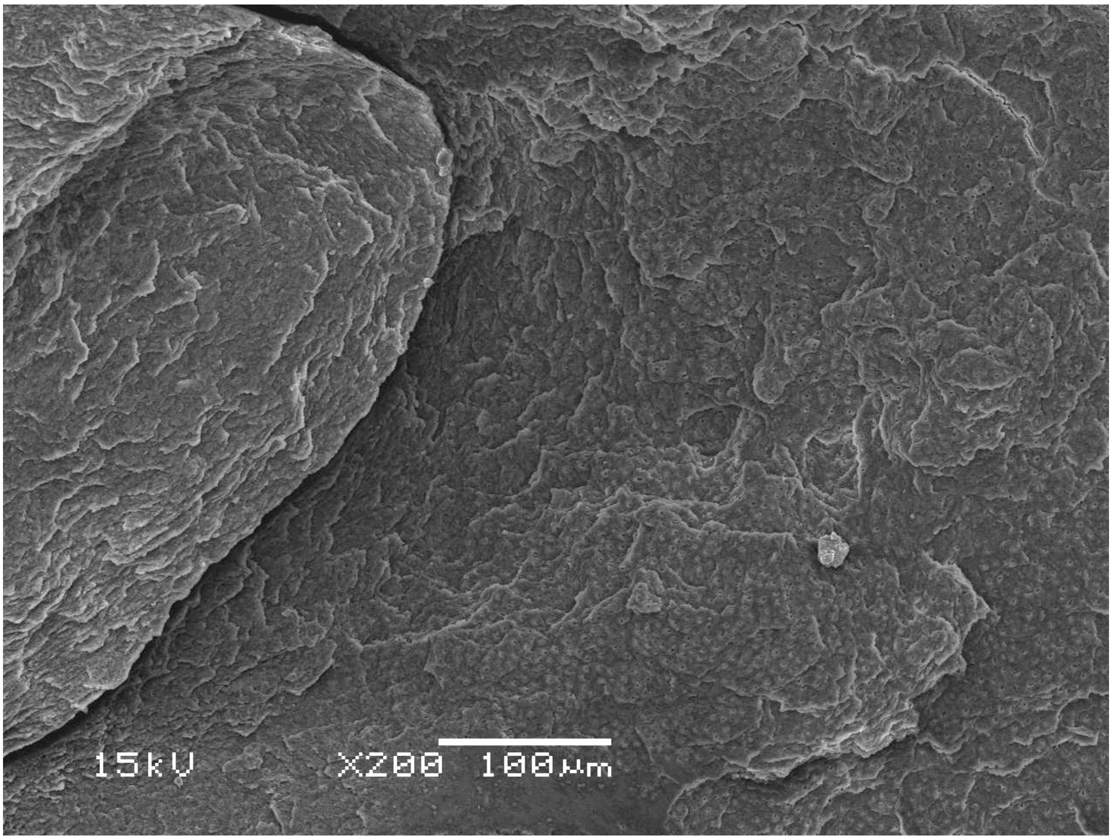


c)

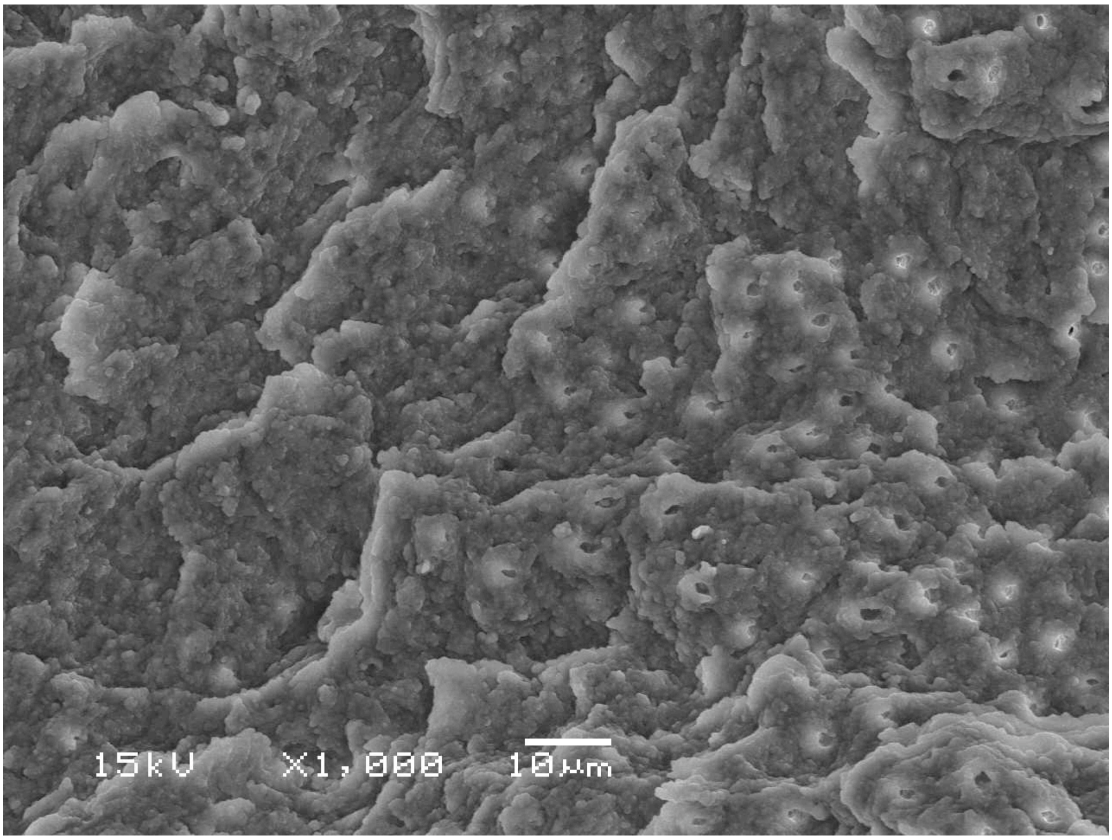


Mid third

d)

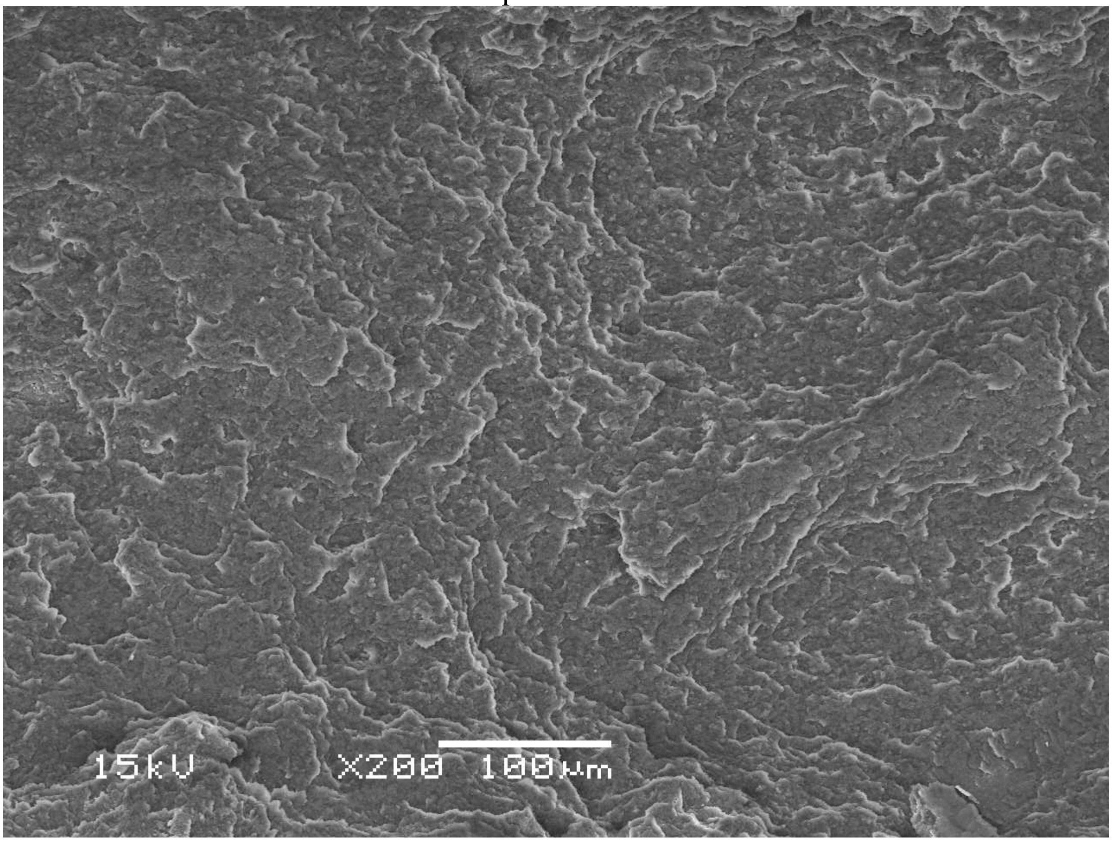


e)



Apical third

f)



g)

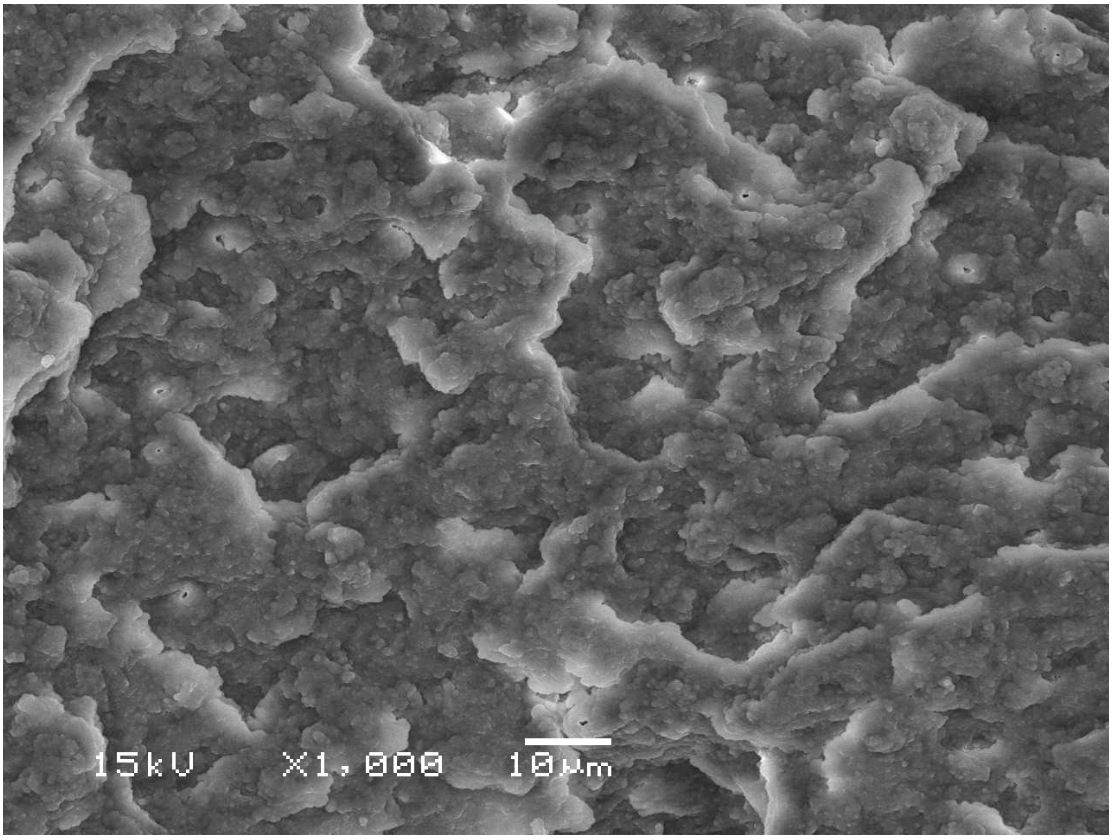
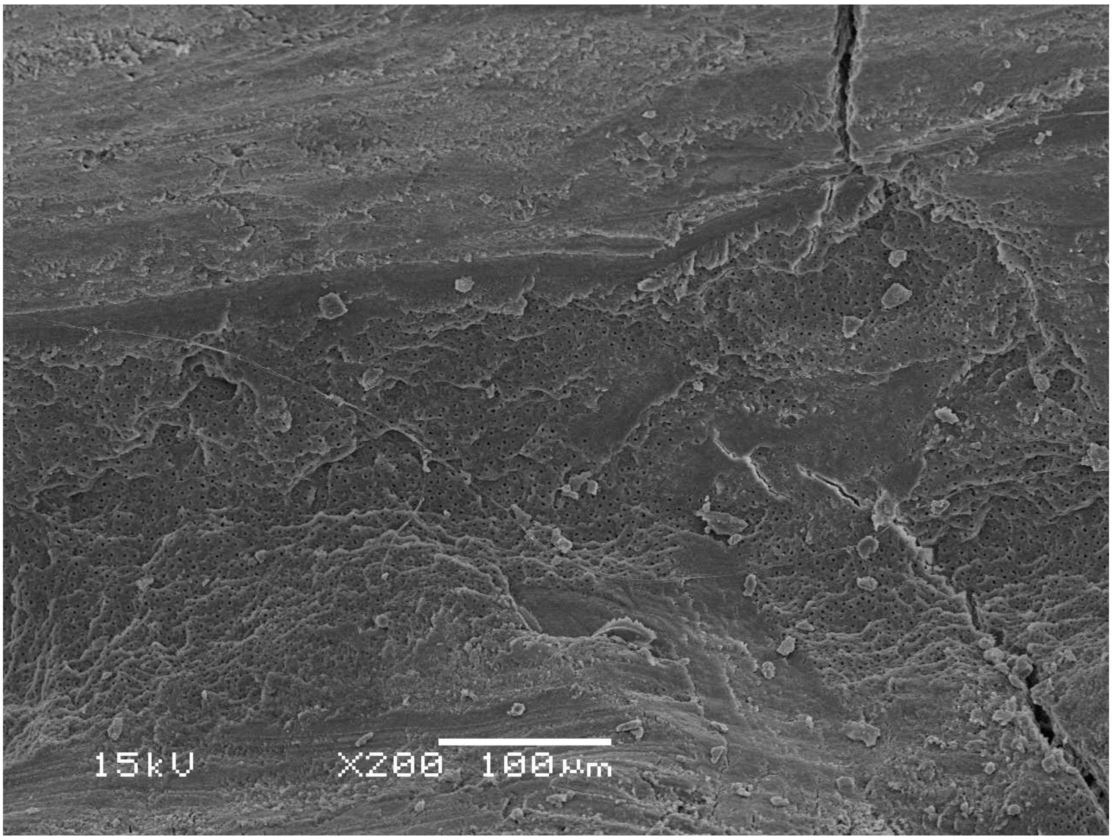


Figure 17 Photomicrographs record the SEM image of a representative tooth from the Er,Cr:YSGG Group ; a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

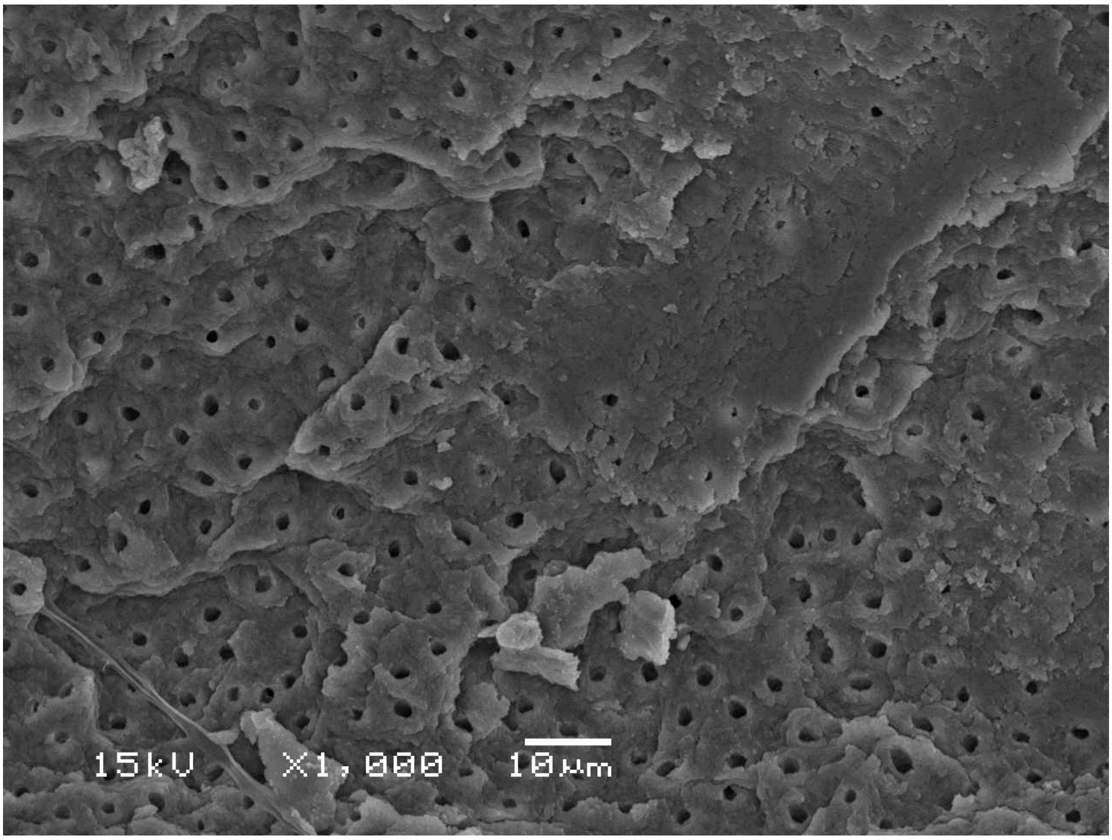
a)

Coronal third

b)

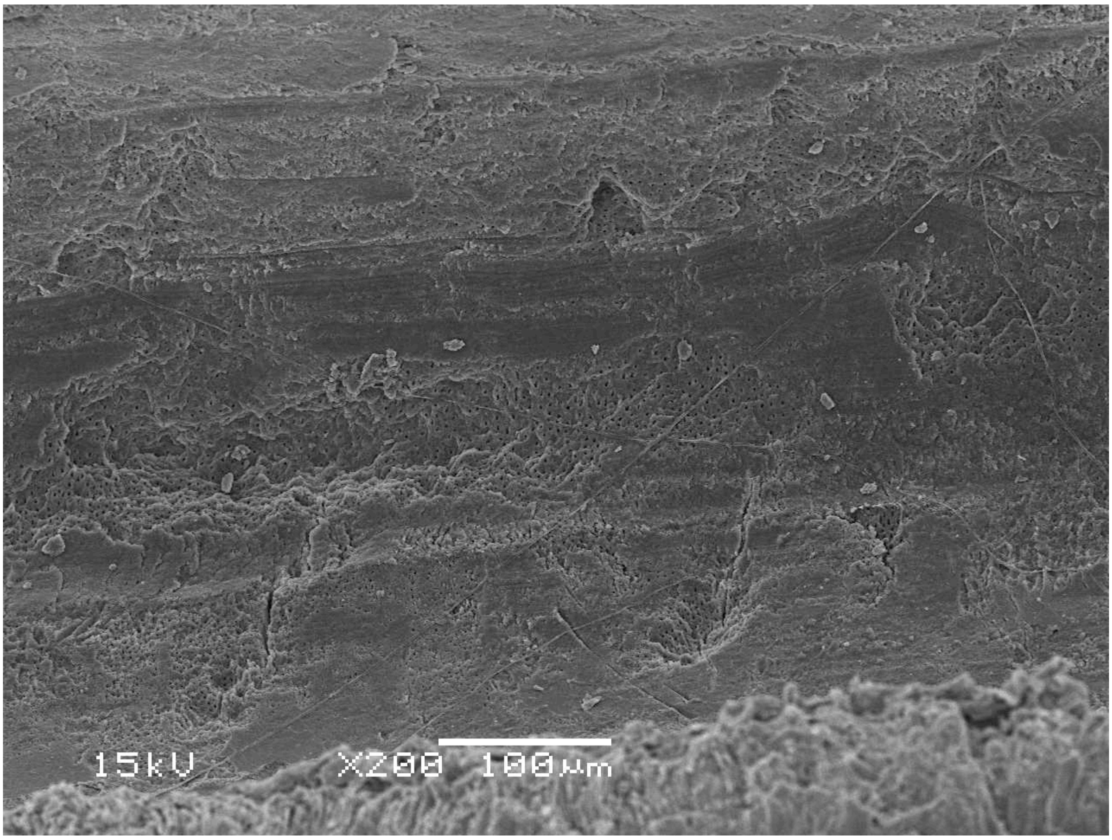


c)

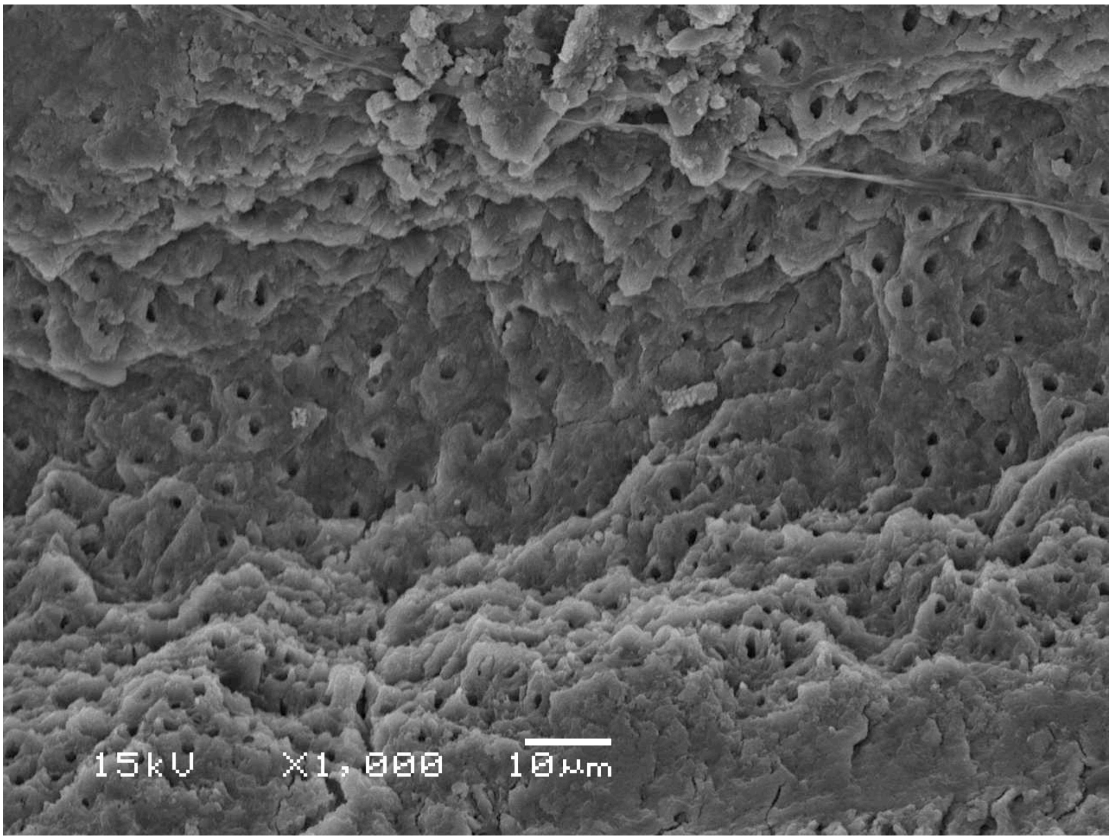


Mid third

d)

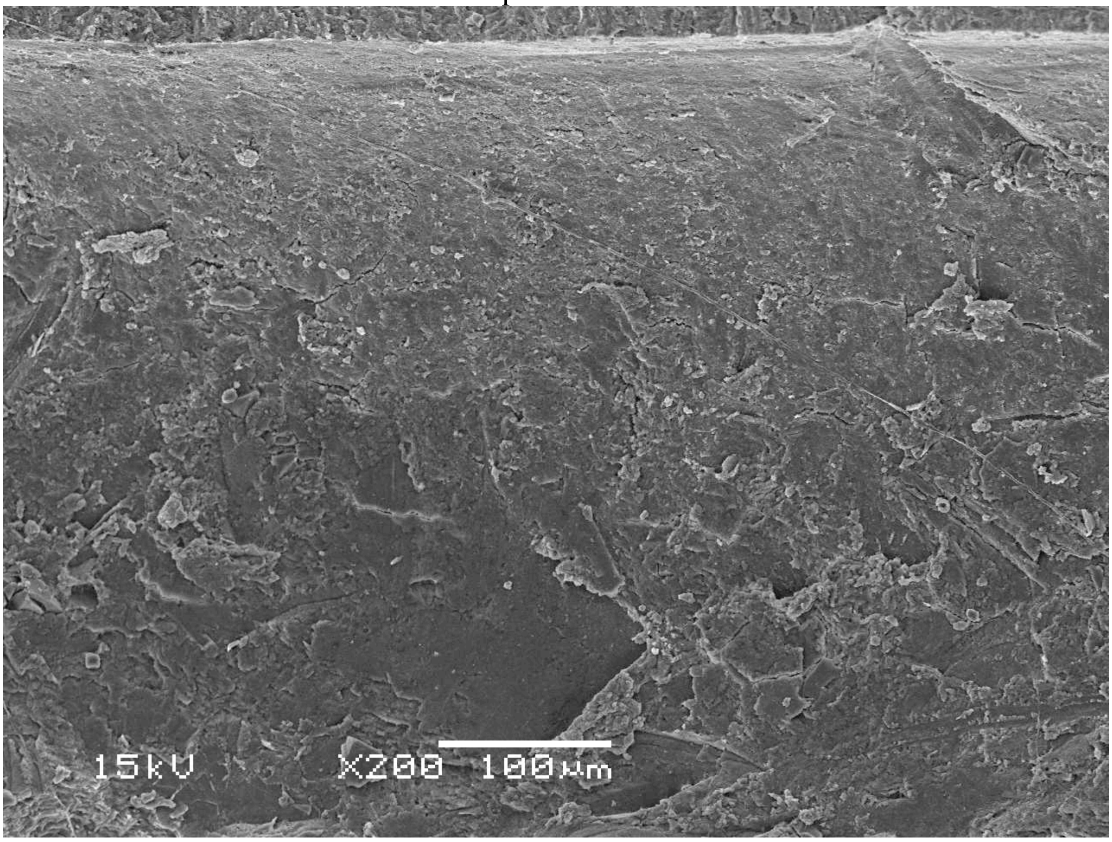


e)



Apical third

f)



g)

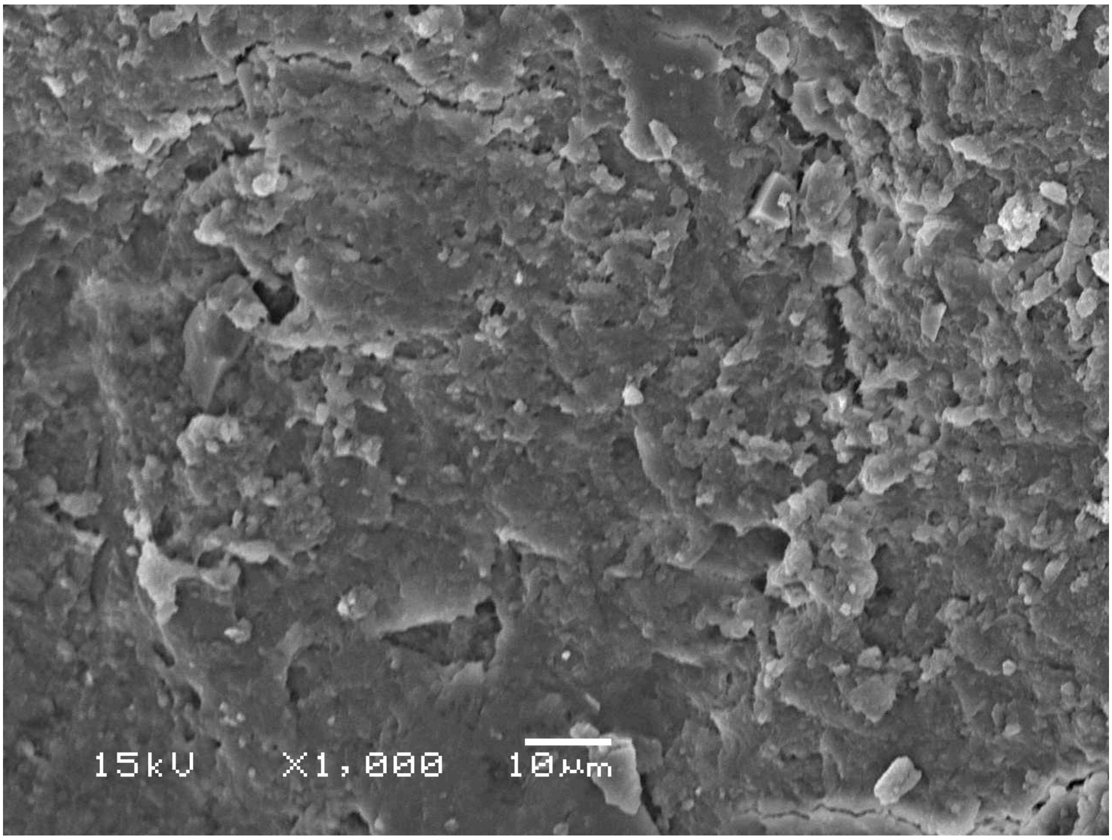
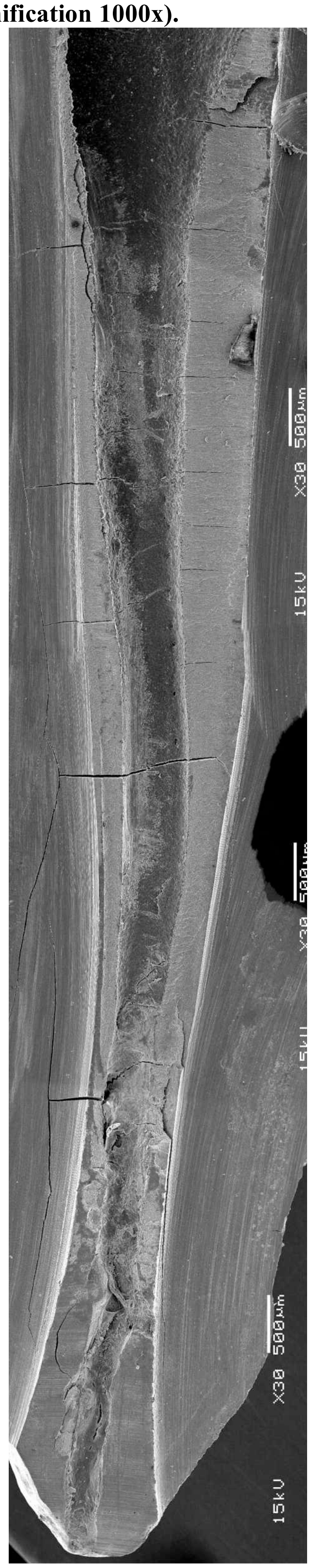


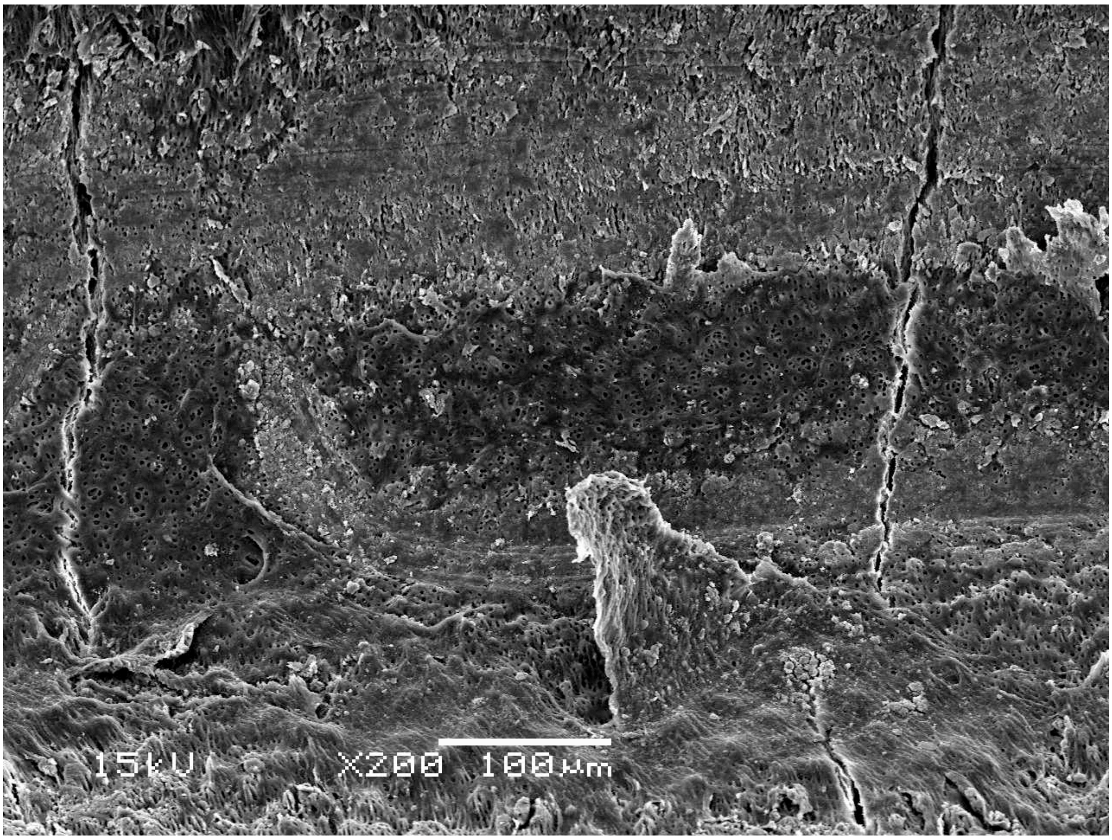
Figure 18 Photomicrographs record the SEM image of a representative tooth from the Unprepared Group ; a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

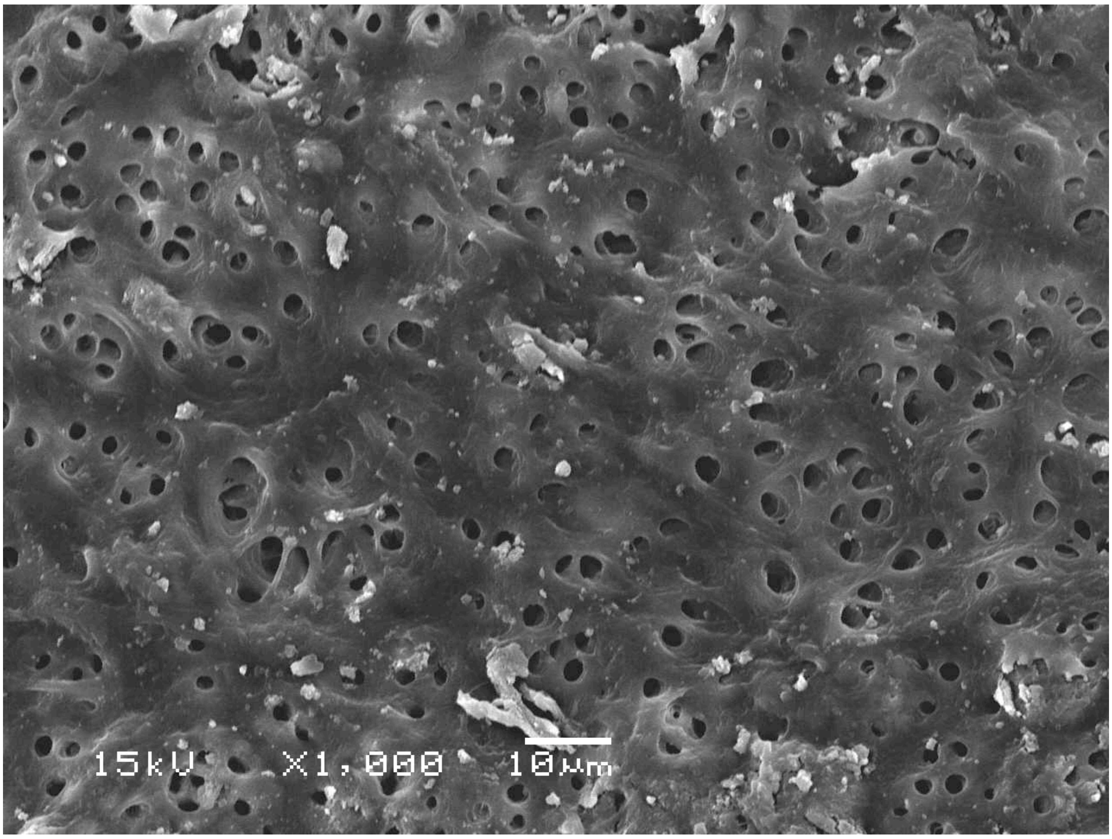


Coronal third

b)

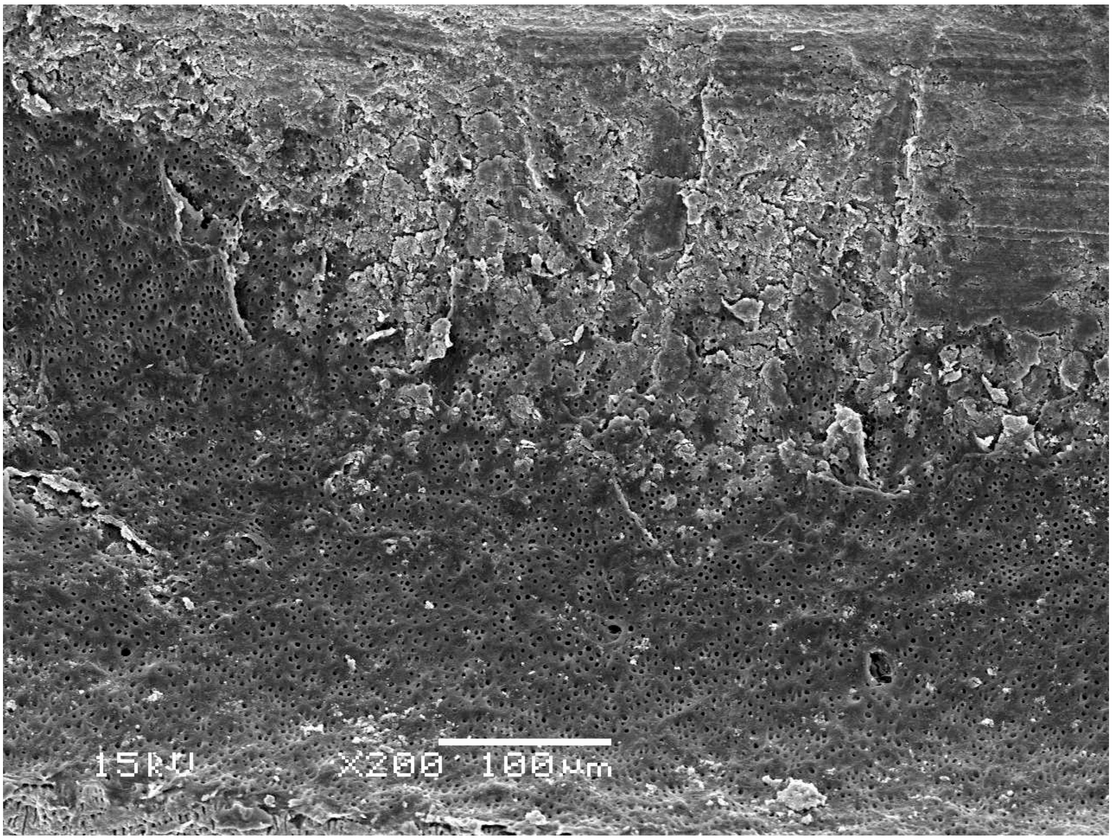


c)

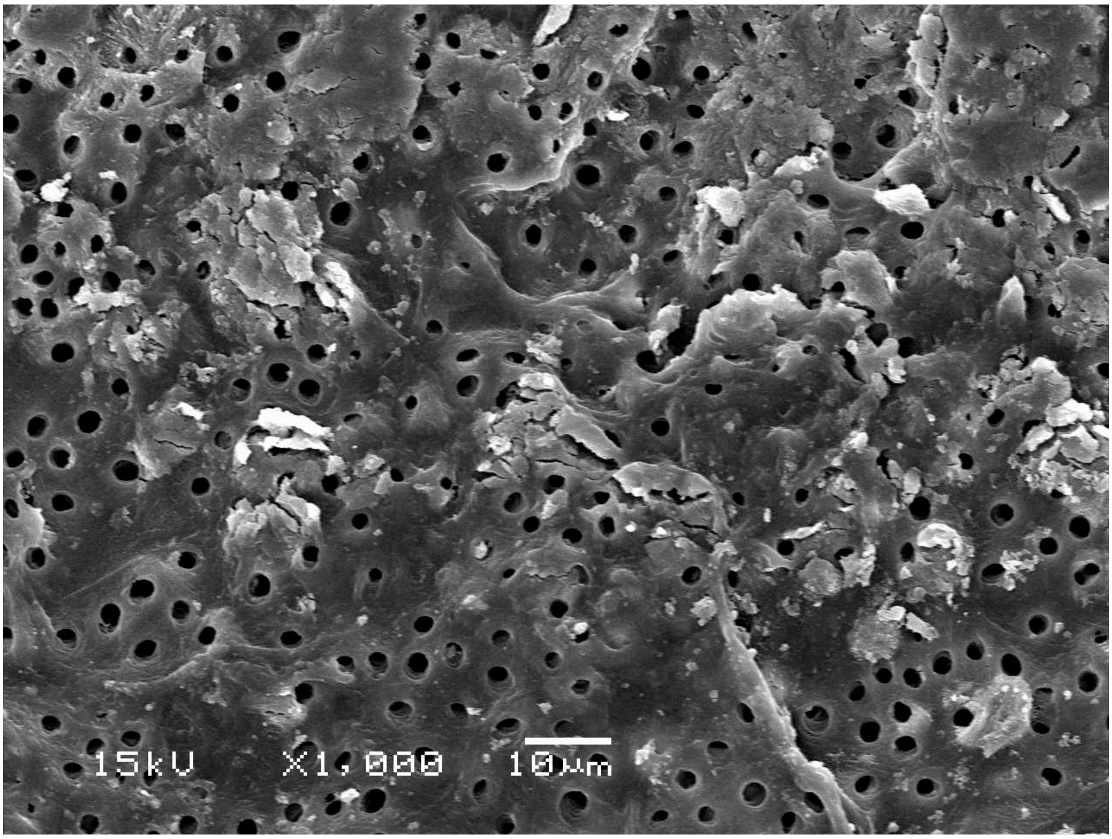


Mid third

d)

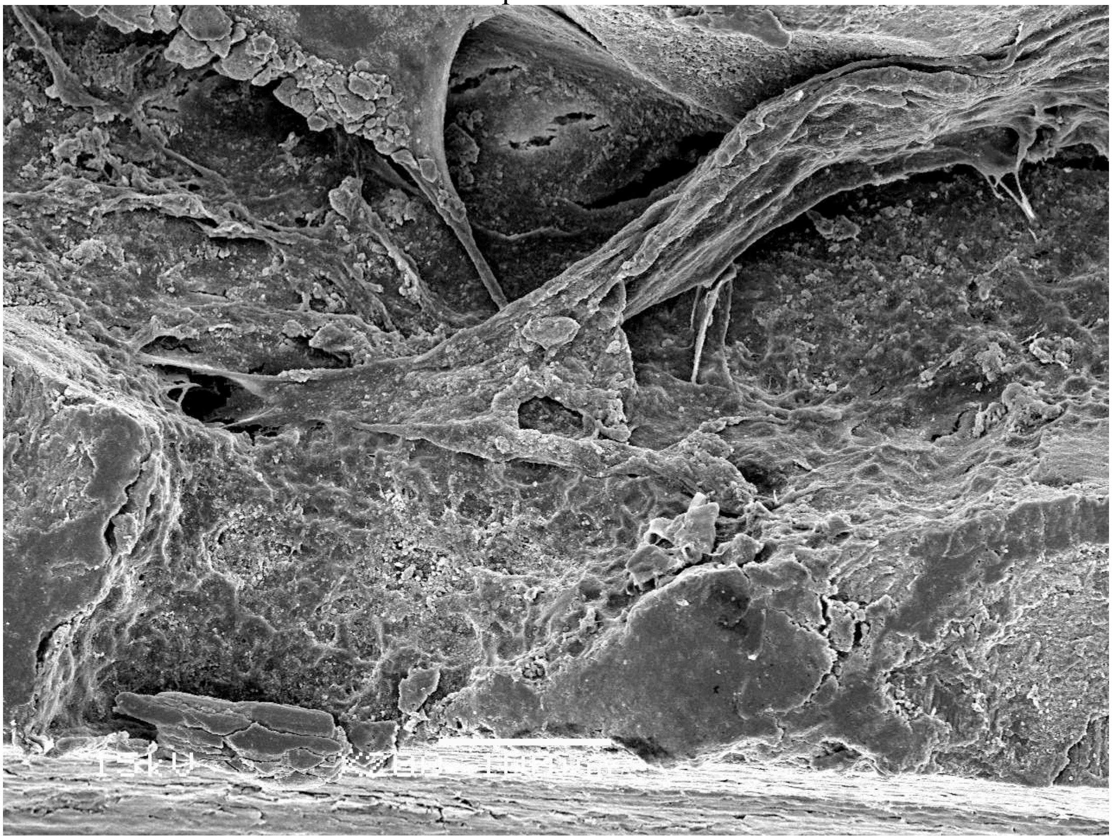


e)

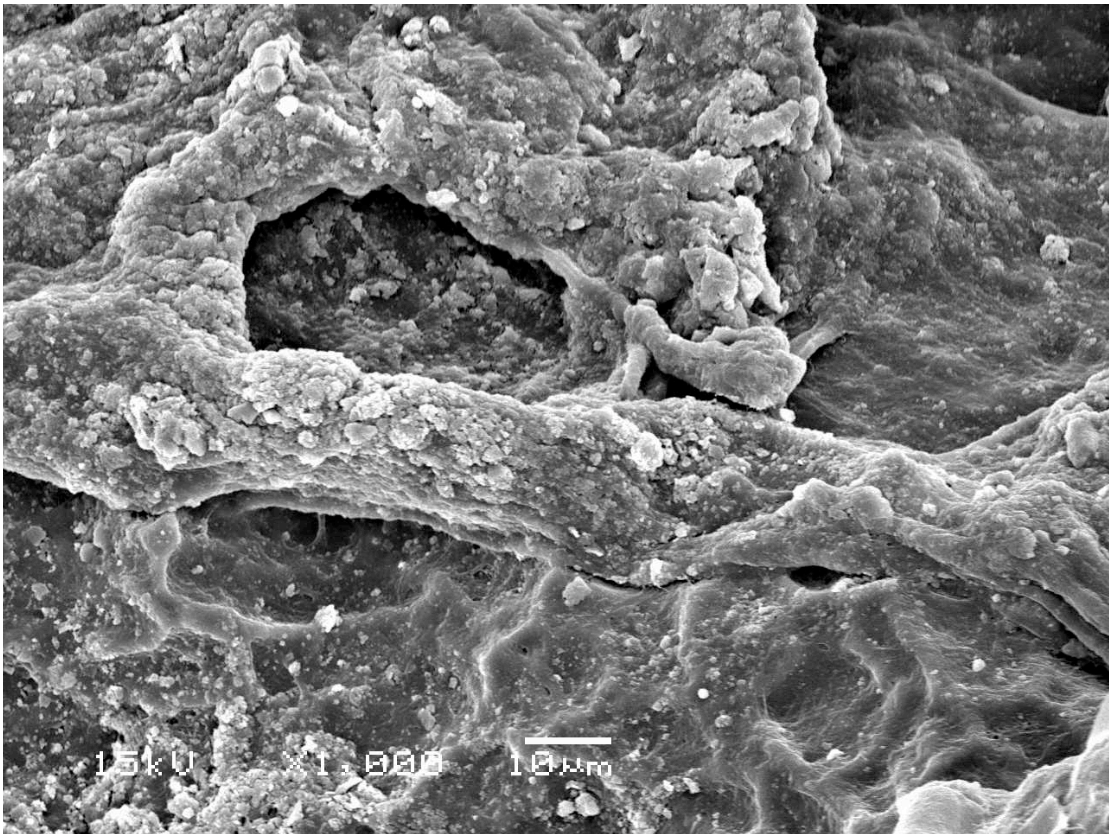


Apical third

f)



g)



To assess the degree of root canal preparation, the teeth were assessed by a scanning electron microscope (JEOL 6460LA, Scanning Electron Microscope, Japan Electron Optics Laboratories, Japan). The SEM images used for evaluation were presented on CRT screens and the images were of representative areas of the root canal preparation at the coronal, middle, and apical thirds. The quality of root canal preparation was scored by three evaluators (2 were blinded) according to the criteria described (Table 7). Photomicrographs were taken to record the assessed image.

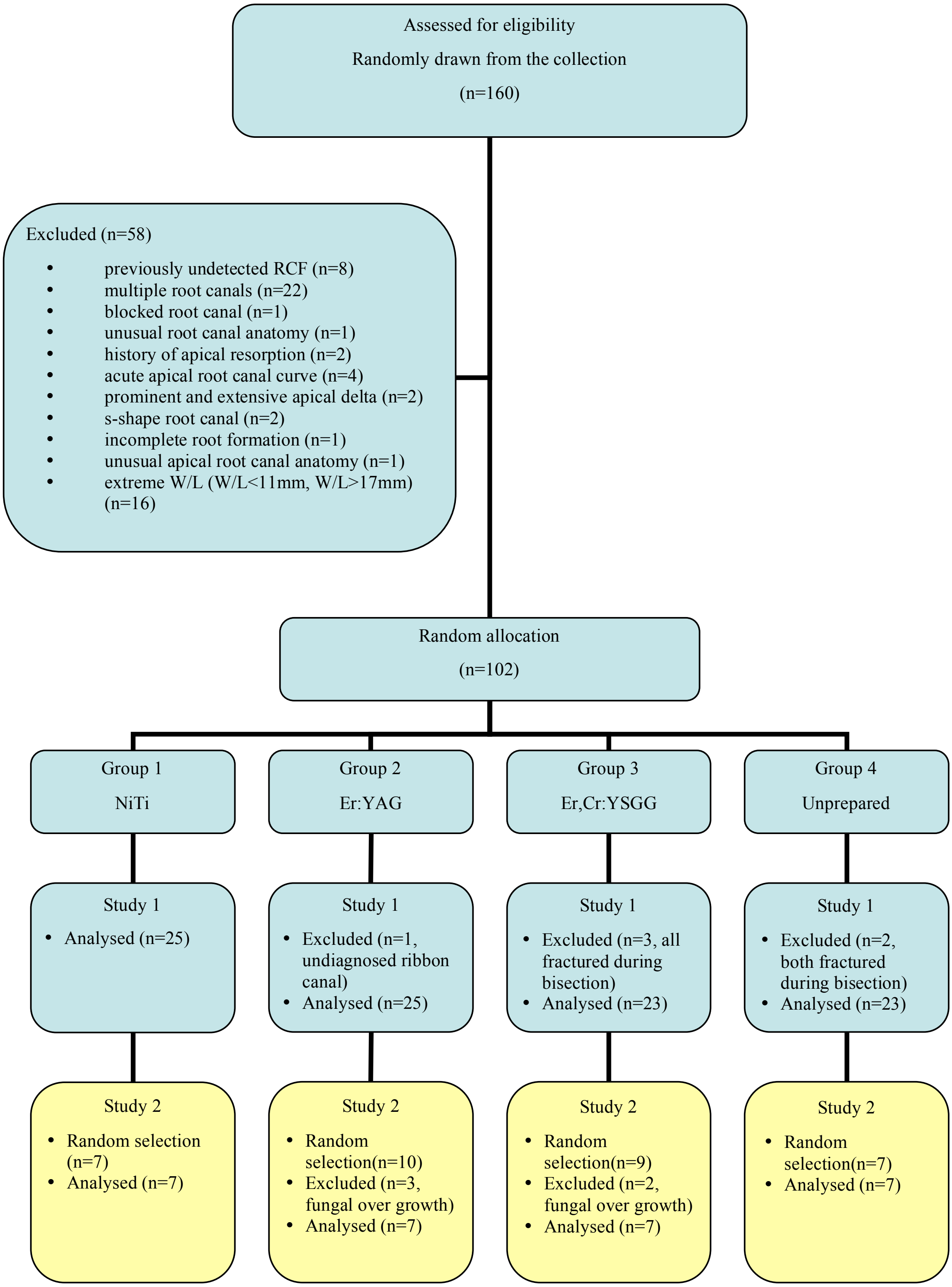
The assessment criteria described by Hulsmann et al [51] was used to assess debris and smear layer but was modified such that the score allocated to each definition was reversed so that the higher the score the more desirable the appraisal. Moreover, scoring of debris was performed using 200x magnification and smear layer was scored using 1000x magnification.

A flow of study teeth through each stage is shown in the following diagram (Figure 19).

Table 7 the criteria used to evaluate the quality of preparation

Criteria	Score	Definition [51]
Debris (dentine chips, pulp remnants, and particles loosely attached to the canal wall)	5	Clean canal wall, only very few debris particles
	4	Few small conglomerations
	3	Many conglomerations; less than 50% of the canal wall covered
	2	More than 50% of the canal wall covered
	1	Complete or nearly complete covering of the canal wall by debris
Smear layer (dentine particles, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigant)	5	No smear layer, orifice of dentinal tubules patent
	4	Small amount of smear layer, some open dentinal tubules
	3	Homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules
	2	The entire root-canal wall covered with a homogenous smear layer, no open dentinal tubules
	1	A thick, (non)homogenous smear layer covering the entire root-canal wall

Figure 19 A flow chart of study teeth



The specimens were randomly sequenced and evaluated by three evaluators, where 2 evaluators did not have previous knowledge of the treatment of the roots or the objectives of the study. The evaluators were trained to assess and score the root canal preparations according to the assessment criteria immediately before the commencement of the evaluation.

Data were recorded directly on to score sheets and then stored in a PC notebook (Compaq 800, Compaq Computer Corporation, Intel®, Celeron® CPU 1.70 GHz, 224MB of RAM, Microsoft® Windows® XP Home Edition). The data were analysed using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA).

Results were analysed for statistical significance using Kruskal-Wallis Multiple-comparison Z-value Test ($P<0.05$) and post hoc comparisons of 2 sample tests using Mann-Whitney U Test ($P<0.0083$, alpha reduced for multiple comparisons).

However, the Modified-Levene Equal-Variance Test suggested that the assumption of equal variance was not met for either the debris score or smear layer score, so the Kruskal-Wallis ANOVA is not valid. The samples are of equal sizes and this characteristic should compensate for unequal variance [52]. Nevertheless, the alternative Mann-Whitney U Test was used with reduced alpha for multiple comparisons.

Results

The box plot illustrates the distribution of overall total scores by group (Figure 20). The stacked bar chart shows the median overall score by group and the components of the median score by assessed criteria (Figure 21). The greater the overall score the better the quality of the clinical root canal preparation.

The Kruskal-Wallis Multiple-comparison Z-value Test ($P<0.05$) found:

1. The median overall total score for the Er:YAG Group was significantly greater than the Unprepared Group ($p<0.05$) .
2. The median overall total score for the NiTi Group was significantly greater than the Unprepared Group ($p<0.05$).
3. The median overall total score for the Er,Cr:YSGG Group was not significantly different from the Er:YAG, NiTi or Unprepared Groups ($p>0.05$).
4. The median overall total score for the Er:YAG Group was not significantly different from the NiTi Group ($p>0.05$).

The histogram shows the frequency of debris scores by group (Figure 22). The greater the debris scores the better the quality of the clinical root canal preparation. The Mann-Whitney U Test ($p<0.0083$) of the median debris scores for each of the groups found:

1. The median debris total score for the Er,Cr:YSGG Group was not significantly different from the Er:YAG, NiTi, or Unprepared Groups.

2. The median debris total score for the Er:YAG Group was not significantly different from the NiTi Group.

3. The median debris total score for the Er:YAG Group was significantly greater than the Unprepared Group.

4. The median debris total score for the NiTi Group was not significantly different from the Unprepared Group.

The histogram shows the frequency of smear layer scores by group (Figure 23). The greater the smear layer score the better the quality of the clinical root canal preparation. The Mann-Whitney U Test ($p<0.0083$) of the median smear layer scores for each of the groups found:

1. The median smear layer total score for the Er,Cr:YSGG Group was significantly less than the NiTi Group.

2. The median smear layer total score for the NiTi Group was significantly greater than the Unprepared Group.

3. The median smear layer total score for the Er,Cr:YSGG Group was not significantly different from the Er:YAG or Unprepared Groups.

4. The median smear layer total score for the Er:YAG Group was not significantly different from the NiTi or Unprepared Groups.

The objective of this study was to determine if either Er:YAG laser or Er,Cr:YSGG laser are comparable to more popular root canal preparation techniques (NiTi rotary instruments). A power analysis of the results was performed and the results were tabulated in Table 8. Hence, if a

significant difference were to be found between the mean overall total scores of the laser experimental groups and the control groups then the appropriate power analysis would be:

1. The Er:YAG Group v the NiTi Group. A power analysis was undertaken and the following statement can be made: Group sample sizes of 1964 and 1964 (655 teeth) achieve 80% power to detect a difference of -0.4 between the null hypothesis that both group means are 24.1 and the alternative hypothesis that the mean of the NiTi Group is 24.5 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

2. The Er,Cr:YSGG Group v the NiTi Group. A power analysis was undertaken and the following statement can be made: Group sample sizes of 100 and 100 (33 teeth) achieve 86.27% power to detect a difference of -1.9 between the null hypothesis that both group means are 22.6 and the alternative hypothesis that the mean of the NiTi Group is 24.5 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

3. The Er,Cr:YSGG Group v the Unprepared Group. A power analysis was undertaken and the following statement can be made: Group sample sizes of 100 and 100 (33 teeth) achieve 81.49% power to detect a difference of 1.8 between the null

hypothesis that both group means are 22.6 and the alternative hypothesis that the mean of the Unprepared Group is 20.8 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Table 8 Tabulated results of a power analysis of mean overall total scores

Comparison	Power	N1	N2	Alpha	Beta	Mean1	Mean2	S1	S2
Overall Total (Er,Cr:YSGG v Er:YAG)	0.83368	150	150	0.00830	0.16632	22.6	24.1	3.6	3.6
Overall Total (Er,Cr:YSGG v NiTi)	0.86266	100	100	0.00830	0.13734	22.6	24.5	3.6	3.6
Overall Total (Er,Cr:YSGG v Unprepared)	0.81485	100	100	0.00830	0.18515	22.6	20.8	3.6	3.6
Overall Total (Er:YAG v NiTi)	0.80018	1964	1964	0.00830	0.19982	24.1	24.5	3.6	3.6

Note: N1 and N2 are the number of items sampled from each population. Alpha is the probability of rejecting a true null hypothesis. Beta is the probability of accepting a false null hypothesis. Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality. Mean2 is the mean of population 2 under the alternative hypothesis. S1 and S2 are the population standard deviations.

A Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task however, the Kappa reliability test between evaluators shows very good agreement (Table 9).[52]

Table 9 Kappa reliability test between evaluators

Kappa	Evaluator 1 (DH)	Evaluator 2 (EB)	Evaluator 3 (MS)
Evaluator 1 (DH)	1.0	…	…
Evaluator 2 (EB)	0.926316	1.0	…
Evaluator 3 (MS)	0.926316	1.000000	1.0

Figure 20 A box plot of overall score by group

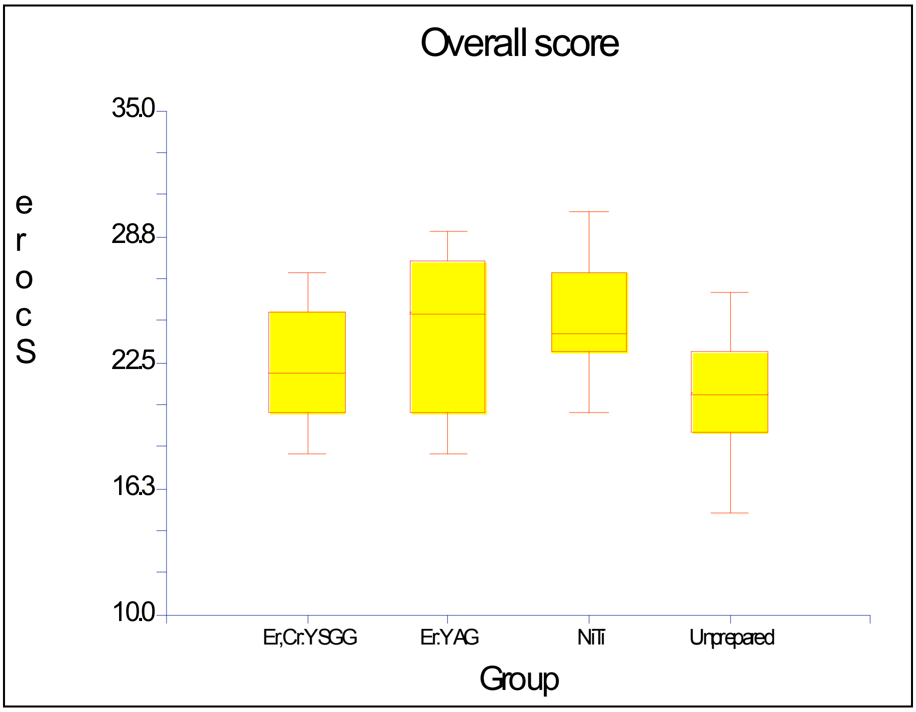


Figure 21 A bar chart of median overall score by group

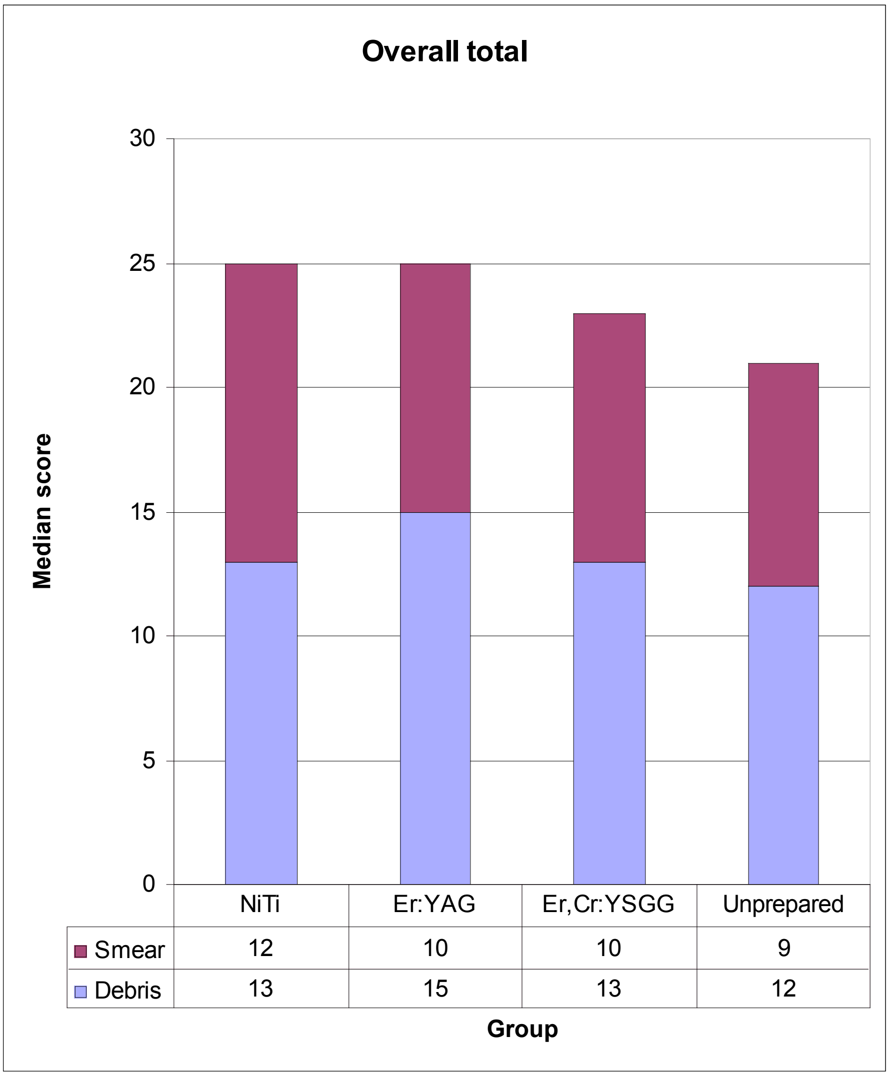
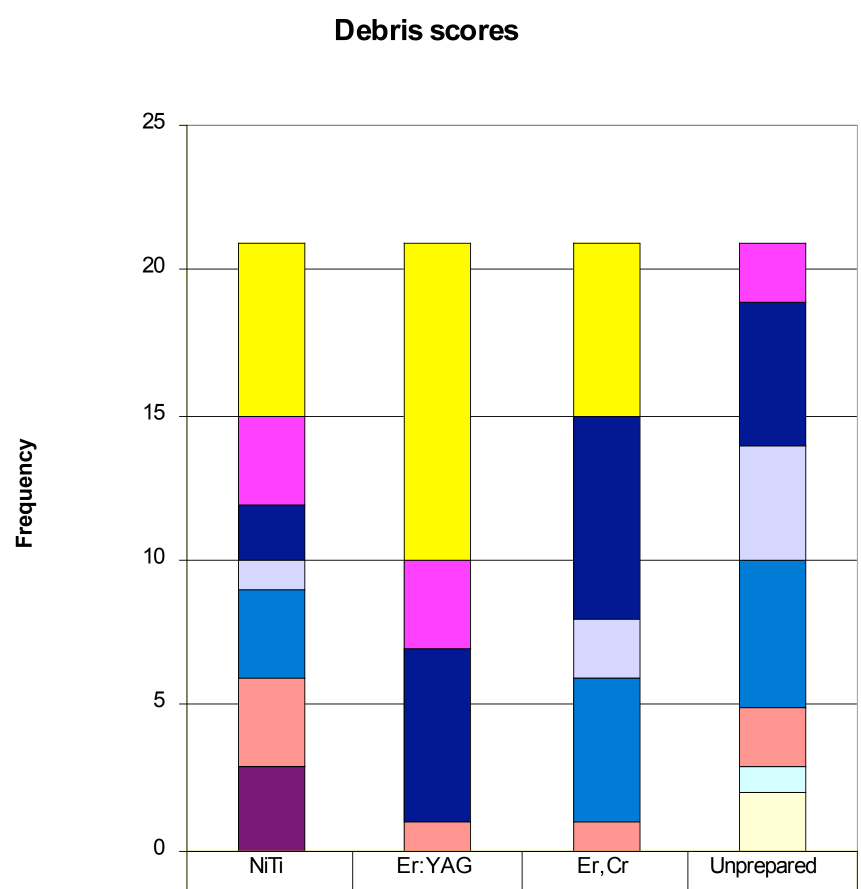


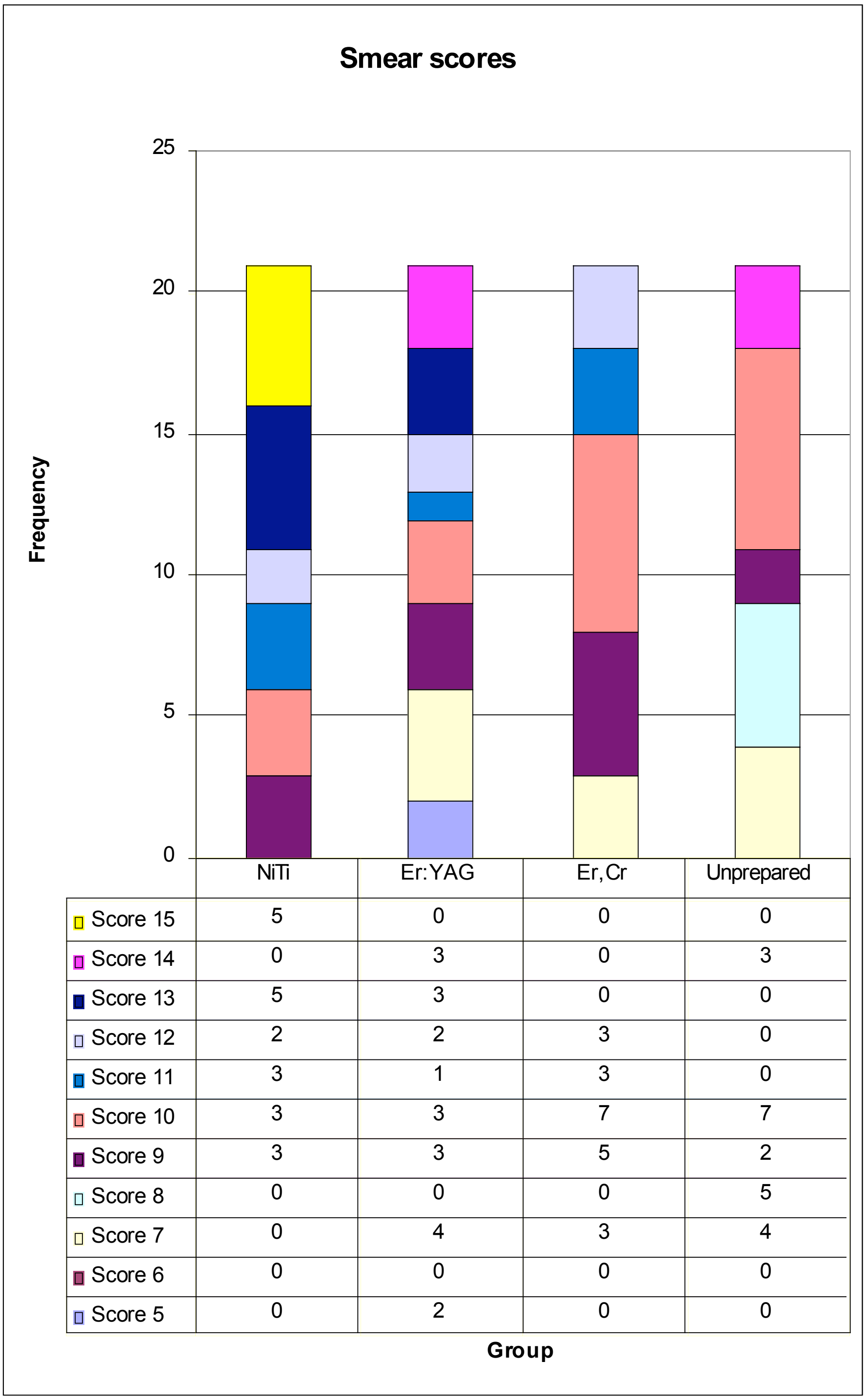
Figure 22 A histogram of debris score by group



	NiTi	Er:YAG	Er,Cr	Unprepared
Score 15	6	11	6	0
Score 14	3	3	0	2
Score 13	2	6	7	5
Score 12	1	0	2	4
Score 11	3	0	5	5
Score 10	3	1	1	2
Score 9	3	0	0	0
Score 8	0	0	0	1
Score 7	0	0	0	2
Score 6	0	0	0	0
Score 5	0	0	0	0

Group

Figure 23 A histogram of smear layer score by group



Discussion

A key objective of successful root canal treatment is debris removal from the root canal in order to eliminate micro-organisms from the root canal system.[1, 2] This study compared the debris removal ability of 2 laser root canal preparation techniques with a rotary NiTi control group and demonstrated that debris from the root canal could not be consistently completely removed. However, the Er:YAG and NiTi Groups had significantly less remnant debris than the Unprepared Group.

The finding that the NiTi Group is effective in removing debris is in general agreement with other studies that have also examined the removal of debris by other rotary NiTi root canal preparation techniques.[40, 51, 53-55]

Moreover, other similar studies [16-18, 29, 30, 37, 39] that investigated debris removal from root canals during root canal preparation were also in general agreement with this study. However, the conclusions from these studies were not supported by either adequate experimental design or statistical methods.

In one study, Takeda et al [16] evaluated the efficacy of Er:YAG laser irradiation in removing debris and smear layer from prepared root canal walls. Thirty-six endodontically treated human mandibular incisor teeth with single root canals were bisected longitudinally and divided into three groups of 12 teeth. Control specimens showed an amount of debris and heavy smear layer obscuring the dentinal tubules at all levels in the canals. Whereas, the root canal walls irradiated by Er:YAG laser were

free of debris, with an evaporated smear layer and open dentinal tubules. However, the study design was to evaluate a difference in medians using ordinal measures between 3 independent groups. A more appropriate statistical analysis would have been to use the Kruskal-Wallis test and not a 2-sample test, Mann-Whitney U test.[52] Furthermore, the study data was ordinal and discrete with only 3 unique values and the continuous variable assumption can not be ignored suggesting a more appropriate statistical analysis would have been to use the Chi-square test. [52, 56] Therefore, the conclusion arrived at by Takeda et al [16] that the Er:YAG laser is effective in removing debris and smear layer from root canal walls was brought into question and must be considered with caution.

In another study, Matsuoka et al [29] evaluated morphologically the capability of Er:YAG laser irradiation for root canal preparation in 40 extracted human teeth which were divided randomly into 2 groups of 20. After laser irradiation, the teeth were bisected and observed by field emission-scanning electron microscopy. Matsuoka et al still found that remnant pulp tissue remained in the root canals after laser irradiation even though they prepared the canals to a size 90 K-type file and irrigated with 5%NaOcl and 3%H2O2 before introducing the Er:YAG laser.. Nevertheless, they observed that debris removal appeared to be complete in some teeth and to depend on which parameters were set on the Er:YAG laser. Therefore, the investigators concluded that Er:YAG laser irradiation is capable of root canal preparation if appropriate parameters are selected relative to the root canal size.

However, caution should be used when considering Matsuoka et al [29] conclusions because control groups were not evaluated and statistical analysis was not carried out on the data. In spite of the study design which was to evaluate a difference in medians using ordinal measures between 2 independent groups. A more appropriate study design would have been to use one of the groups as a control group and collect ordinal data with at least 5 unique values and use a non-parametric 2-sample test, Mann-Whitney U test.[52] The study design as it was described easily lends itself to statistical analysis by the Chi-square test. [52]

Whereas, published literature on the ability of Er,Cr:YSGG laser to remove debris from the root canal is scarce. But there are 2 similar studies [37, 39] that observed that debris could also be removed with Er,Cr:YSGG laser. However, both of these studies contributed a low level of evidence to the literature that was of poor quality. Neither study performed any statistical analysis on their data and simply summarised their observations on the morphology of the root canal surface.

For example, Yamazaki et al [37] evaluated the morphological changes in root canal walls as a result of intra-canal irradiation by Er,Cr:YSGG laser under various conditions on 60 extracted single-rooted human teeth. This group of investigators evaluated the root canals by stereoscopy and scanning electron microscopy. They observed the root canals to be free of debris in the teeth irradiated with cooling. However, the root canals were all instrumented to a size 80 K-type file at the working length with 5%NaOCl and 3%H_2O_2 before introduction of the Er,Cr:YSGG laser. The investigators concluded that Er,Cr:YSGG laser irradiation with water

spray cooling is a useful method for removal of debris from root canals. However, these conclusions by Yamazaki et al [37] contrast with this study findings that the Er,Cr:YSGG did not have significantly less debris than the Unprepared Group

A point of differentiation between the present study and similar studies is that they were all instrumented to a large apical file size (from a 25 K-type file up to a 90 K-type file) and sodium hypochlorite was used for irrigation prior to the introduction of the laser. Sodium hypochlorite is well known to effectively dissolve loose organic debris from the root canal.[8, 20, 21] Whilst the present study either pre-prepared the canals to a 25 K-type file in the Er,Cr:YSGG Group or a 15 K-type file in the Er:YAG Group, and during the preparation only saline was used for irrigation. Thus, any reduction in debris from the root canals was largely due to the mechanical processes of root canal preparation technique employed in each group and not from prior instrumentation or any irrigation solutions used.

Even though, the Er:YAG Group was found to have less debris than the Unprepared Group; this study shows that root canal preparation using Er:YAG or Er,Cr:YSGG lasers alone is not sufficient to remove debris without concurrent use of irrigation solutions to dissolve and flush out debris. Additionally, the Er,Cr:YSGG and Er:YAG lasers do not perform better than simpler conventional rotary NiTi root canal preparation techniques that use generally accepted irrigation regimens with sodium hypochlorite and EDTA irrigation solutions.

The second goal of this study was to determine if lasers could remove the smear layer from root canal walls after their preparation with mechanical instruments. Earlier studies have shown the potential of laser in the removal of smear layer from root canal walls.[15-17, 19, 29, 30, 37, 39] Yet, the conclusions from these studies were not supported by either satisfactory experimental design or statistical methods.

For instance, Takeda et al [19] evaluated 60 human teeth for the effects of three endodontic irrigants and two types of laser on a smear layer created by hand instrumentation. The teeth were divided into 5 groups of 12 teeth each, after the interventions the teeth were bisected and evaluated by SEM against predefined criteria. The data was analysed for significant differences between the group medians by the Kruskal-Wallis test and the Mann-Whitney U test (used as a post hoc test). Takeda et al [19] were able make a number of conclusions from their data that included that the CO_2 laser was useful in removing and melting the smear layer on the instrumented root-canal walls and the Er:YAG laser was the most effective in removing the smear layer from the root-canal wall. However, these conclusions must be considered cautiously because their study data was ordinal and discrete with only 4 unique values and the continuous variable assumption can not be ignored suggesting a more appropriate statistical analysis would have been to use the Chi-square test.[52, 56] Moreover, the Mann-Whitney U test was used to confirm the significant differences between pairs of groups. When several planned comparisons are made, the probability of obtaining significance by chance is increased. In the case of Takeda et al [19] 10 independent

comparisons between 5 groups, all at ά=0.01, the probability of one or more significant results is 10 x 0.01 = 0.1. One way to compensate for multiple comparisons is to decrease the ά level, and one way to decrease the ά level is to divide ά by the number of comparisons made.[52]

Nevertheless, this study could not establish if smear layer could be removed from the root canal wall by the Er:YAG Group any better than the NiTi group due to insufficient statistical power of this study. On the other hand, the study did demonstrate that the Er,Cr:YSGG Group did not remove the smear layer as well as the NiTi Group.

The ability of the lasers to remove smear layer and debris from the root canal walls was best demonstrated in this study through evaluation of the overall total score. The overall total score of the assessment criteria most clearly demonstrates the differences between the experimental and control groups of this study. Similar assessment criteria have been used in previous studies [40, 51, 53-55] to assess conventional root canal preparation techniques (Table 7).

One of the main reasons that these differences were seen was because the criteria were appropriately defined and allocated scores from 1 to 5 which by convention, allows the discrete and ordinal nature of the data to be considered as continuous variable data for the purposes of statistical analysis by Kruskal-Wallis Test or Mann-Whitney U Tests.[56] Whereas, other studies [15-17, 19, 29, 30, 37] have been designed with assessment criteria that only give rise to data that were discrete (i.e. less than 5 unique values), so by convention the continuous variable assumption was not

met which is required for Kruskal-Wallis Test or Mann-Whitney U Tests.[56]

The study design appears to be valid because there was a significant difference between the control groups. Thus, the overall total score gave a balanced view of the ability of the Er:YAG and Er,Cr:YSGG lasers to remove debris and smear layer from root canals.

When the overall total score was considered, the Er:YAG Group appeared to be as equally as effective as the NiTi Group and significantly better than the Unprepared Group. Power analysis found that the study groups would need to have at least 655 teeth in each group (or a study sample size of 2620 teeth) to have greater than 80% power to detect a significant difference between the Er:YAG and NiTi Groups. Therefore, for all practical purposes the differences between the Er:YAG and NiTi Groups can be considered very small and the Er:YAG Group can be considered comparable to the NiTi Group. In other words, the difference between the Er:YAG root canal preparation technique and rotary NiTi root canal preparation technique is not clinically significant in terms of overall debris and smear layer removal.

However, when considering the differences between the Er,Cr:YSGG Group and control groups, a power analysis determined that the groups should contain 33 teeth each or a study sample size of 132 teeth. The magnitude of this sample size can not be considered so large that the Er,Cr:YSGG Group is equivalent to either of the control groups. Therefore, this study lacked statistical power to determine a difference between the Er,Cr:YSGG Group and control groups.

Further, research with greater statistical power is required if a similar study is to determine a statistically significant difference between the abilities of rotary NiTi techniques and Er,Cr:YSGG laser to remove debris and smear layer from root canals. If this study were to have sufficient power, then a sample size of 200 teeth and not 32 teeth would be required as established by power analysis. Moreover, if the study size was increased to 200 teeth then it would also have sufficient power to detect a difference between both lasers groups, and the Er,Cr:YSGG Group and the controls.

Additional teeth had to be added to the experimental groups in this study because of fungal contamination after splitting the teeth and prior to SEM. The group sizes were kept approximately equal to eliminate the concern about the assumption of equal variance required for a Kruskal-Wallis Test.[52] Fungal contamination of the specimens may have been due to either the pre-existence of oral commensal fungi or due to inadequate handling of the specimens after they were bisected. This problem did not make a significant impact on the results of the study because the group sizes were sufficient to compensate for the exclusion of badly contaminated specimens from the study (n=5).

Furthermore, in this study a representative area for analysis was subjectively determined; however, a systematic method may have been more appropriate and may have increased the power of the study without increasing the numbers of specimens required. For example, a more thorough assessment of the root surface by placing a grid over the root canal and randomly selecting 3, 5 or even 7 grid squares per root third to

take photomicrographs. Such a systematic approach to the selection of root surface areas to be assessed would have provided more data and greater statistical power to determine a difference between the study groups. One such method was used in a similar study by Jeon et al [49] who evaluated rotary root canal preparation techniques. However, this method was felt to be unnecessarily complex and on balance the authors felt that the subjective method used in this study was adequate.

The reliability of the study design was tested and assessed by the Kappa reliability test, which was used to assess inter-evaluator agreement. There was very good agreement between evaluators which reflects the subjective and ordinal nature of the assessment criteria and the precision of the criteria definitions.

The high Kappa reliability statistic demonstrates that there was minimal bias when judging the specimens and that the unblinded assessments by ER were unbiased. Therefore, the assessments by ER were included in the study despite not being blinded to the treatment of the roots or the objectives of the study.

Furthermore, a second evaluation of the photomicrographs to assess intra-evaluator reliability was not carried out because a power analysis of preliminary results demonstrated that a significant difference between the groups was unlikely to be established.

This is an in vitro study that has been deliberately limited to a sample of single roots with straight and uncomplicated root canal systems that have standardised straight line access to the root canal. These limitations to

the sample allowed the direct comparison of 2 laser root canal preparation techniques. Caution should be used in extrapolating this study's results to clinical use without more research to demonstrate that lasers can be used successfully in vivo and show significant advantages over current conventional and modern root canal preparation techniques.

The laser beam is thought to have the ability to remove debris and produce a tapered root canal preparation [12, 18, 22] but it is hard to irradiate the lateral canal walls because the laser is emitted straight ahead, making it almost impossible to irradiate the lateral canal walls.

This study and the work of others suggests that it is necessary to improve the fibre tip and the method in order to irradiate all areas of root canal walls.[12, 18, 31, 37, 57-60] The recent development of thinner laser tips (Er,Cr:YSGG fibres as little as 200μm, and Er:YAG fibres from 285μm), which have not been used in similar previous studies has allowed the laser to be used more effectively within root canals, without the necessity for excessive enlargement of the root canal. However, this study demonstrates that it is not enough to have a thin flexible laser fibre, a laser tip that can irradiate the lateral canal walls is also necessary. Such as a laser tip that provides an annular cutting configuration of the laser energy beam.[18] Yamazaki et al [37] noted that the tip geometry may be more important than thickness of the fibre allowing the laser fibre to cut sideways and follow the curves of the root canal and avoid the formation of unnecessary root canal preparation aberrations such as ledges and zips.

Recently, Stabholz [57] demonstrated the potential of a newly developed side firing laser tip, the RCLase Side-firing Spiral Tip in an SEM study

of 20 extracted human teeth. The investigators observed that by using the Er: YAG laser irradiation with the RCLase Side-firing Spiral Tip the root canal system can be efficiently cleaned. However, this tip was designed for the cleansing of root canals following their bio-mechanical preparation with NiTi rotary files and not to prepare root canals with laser irradiation alone as in this study.

In this study, some of the objectives of Er:YAG experimental root canal preparation technique were met. In particular, the experimental technique could consistently remove debris and smear layer from the surface of the root canal preparations and was comparable to the NiTi Group. However, none of the groups were able to consistently demonstrate root surfaces to be free of debris and smear layer (Figures 22-23).

However, despite the promising performance of the experimental Er:YAG root canal preparation technique in terms of debris and smear layer removal other equally important characteristics of the root canal preparation need to be considered. For example, the shaping ability of the Er:YAG technique and development of iatrogenic aberrations during root canal preparation.[50]

Conclusions

In conclusion and under the conditions of this study, the experimental Er:YAG laser root canal preparation technique can be considered as good as the NiTi Group in terms of debris and smear layer removal from the

walls of a root canal. This is especially true for teeth with large single straight root canals.

On the other hand, this study had insufficient statistical power to conclude that the Er,Cr:YSGG Group was comparable to the NiTi Group.

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Appendix 1 Sample size determination

Study 1 Two-Sample T-Test Power Analysis

Based on 0.8 power to detect a significant difference (P=0.0083, two-sided) 20 teeth will be required for each study group. To compensate for lost teeth, 25 teeth (100 teeth in total) in each group will be required. Note each tooth will be evaluated by 3 different evaluators creating an effective group sample size of 75.

Two-Sample T-Test Power Analysis was made using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA).

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80000	10	10	1.000	0.00830	0.20000	9.1	6.0	2.0	2.0
0.80000	20	20	1.000	0.00830	0.20000	8.2	6.0	2.0	2.0
0.80000	30	30	1.000	0.00830	0.20000	7.8	6.0	2.0	2.0
0.80000	40	40	1.000	0.00830	0.20000	7.6	6.0	2.0	2.0
0.80000	50	50	1.000	0.00830	0.20000	7.4	6.0	2.0	2.0
0.80000	60	60	1.000	0.00830	0.20000	7.3	6.0	2.0	2.0
0.80000	70	70	1.000	0.00830	0.20000	7.2	6.0	2.0	2.0
0.80000	80	80	1.000	0.00830	0.20000	7.1	6.0	2.0	2.0
0.80000	90	90	1.000	0.00830	0.20000	7.0	6.0	2.0	2.0
0.80000	100	100	1.000	0.00830	0.20000	7.0	6.0	2.0	2.0
0.80000	10	10	1.000	0.00830	0.20000	11.1	8.0	2.0	2.0
0.80000	20	20	1.000	0.00830	0.20000	10.2	8.0	2.0	2.0
0.80000	30	30	1.000	0.00830	0.20000	9.8	8.0	2.0	2.0
0.80000	40	40	1.000	0.00830	0.20000	9.6	8.0	2.0	2.0
0.80000	50	50	1.000	0.00830	0.20000	9.4	8.0	2.0	2.0
0.80000	60	60	1.000	0.00830	0.20000	9.3	8.0	2.0	2.0
0.80000	70	70	1.000	0.00830	0.20000	9.2	8.0	2.0	2.0
0.80000	80	80	1.000	0.00830	0.20000	9.1	8.0	2.0	2.0
0.80000	90	90	1.000	0.00830	0.20000	9.0	8.0	2.0	2.0
0.80000	100	100	1.000	0.00830	0.20000	9.0	8.0	2.0	2.0
0.80000	10	10	1.000	0.00830	0.20000	13.1	10.0	2.0	2.0

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80000	20	20	1.000	0.00830	0.20000	12.2	10.0	2.0	2.0
0.80000	30	30	1.000	0.00830	0.20000	11.8	10.0	2.0	2.0
0.80000	40	40	1.000	0.00830	0.20000	11.6	10.0	2.0	2.0
0.80000	50	50	1.000	0.00830	0.20000	11.4	10.0	2.0	2.0
0.80000	60	60	1.000	0.00830	0.20000	11.3	10.0	2.0	2.0
0.80000	70	70	1.000	0.00830	0.20000	11.2	10.0	2.0	2.0
0.80000	80	80	1.000	0.00830	0.20000	11.1	10.0	2.0	2.0
0.80000	90	90	1.000	0.00830	0.20000	11.0	10.0	2.0	2.0
0.80000	100	100	1.000	0.00830	0.20000	11.0	10.0	2.0	2.0

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

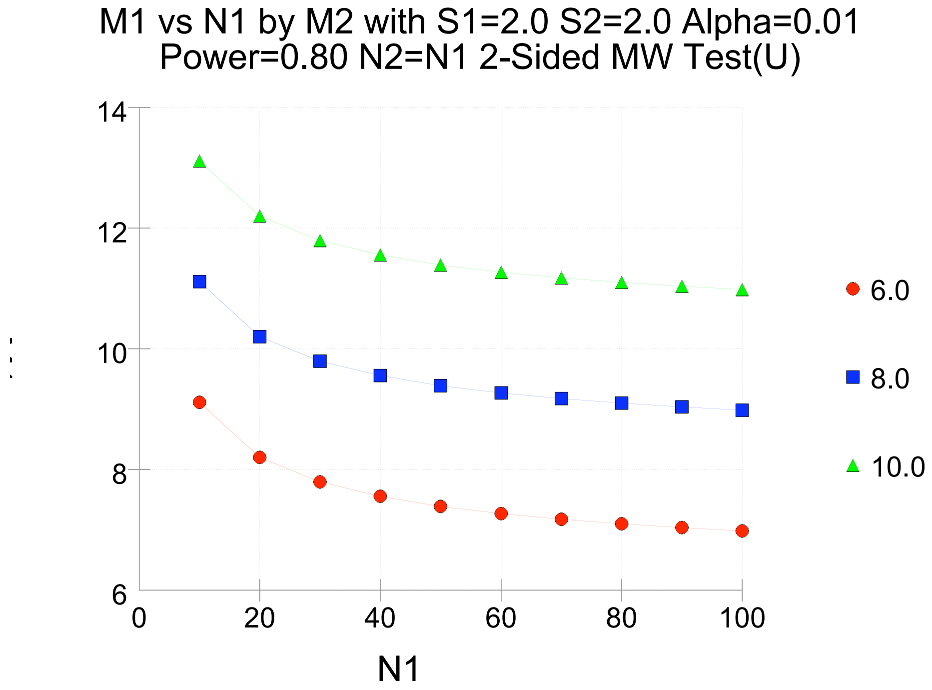
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 60 and 60 achieve 80% power to detect a difference of 1.3 between the null hypothesis that both group means are 9.3 and the alternative hypothesis that the mean of group 2 is 8.0 with known group standard deviations of 2.0 and 2.0 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Study 2 Two-Sample T-Test Power Analysis

Based on 0.8 power to detect a significant difference (P=0.0083, two-sided) 5 teeth will be required for each study group. To compensate for lost teeth, 7 teeth (21 teeth in total) in each group will be required. Note each tooth will be evaluated by 3 different evaluators creating an effective group sample size of 84.

Two-Sample T-Test Power Analysis was made using NCSS 2000/PASS 2000 Dawson Edition (NCSS Statistical Software, Utah, USA).

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80000	6	6	1.000	0.00830	0.20000	21.0	15.0	3.0	3.0
0.80000	9	9	1.000	0.00830	0.20000	21.0	16.1	3.0	3.0
0.80000	12	12	1.000	0.00830	0.20000	21.0	16.7	3.0	3.0
0.80000	15	15	1.000	0.00830	0.20000	21.0	17.2	3.0	3.0
0.80000	18	18	1.000	0.00830	0.20000	21.0	17.5	3.0	3.0
0.80000	21	21	1.000	0.00830	0.20000	21.0	17.8	3.0	3.0
0.80000	24	24	1.000	0.00830	0.20000	21.0	18.0	3.0	3.0
0.80000	27	27	1.000	0.00830	0.20000	21.0	18.2	3.0	3.0
0.80000	30	30	1.000	0.00830	0.20000	21.0	18.3	3.0	3.0
0.80000	6	6	1.000	0.00830	0.20000	24.0	18.0	3.0	3.0
0.80000	9	9	1.000	0.00830	0.20000	24.0	19.1	3.0	3.0
0.80000	12	12	1.000	0.00830	0.20000	24.0	19.7	3.0	3.0
0.80000	15	15	1.000	0.00830	0.20000	24.0	20.2	3.0	3.0
0.80000	18	18	1.000	0.00830	0.20000	24.0	20.5	3.0	3.0
0.80000	21	21	1.000	0.00830	0.20000	24.0	20.8	3.0	3.0
0.80000	24	24	1.000	0.00830	0.20000	24.0	21.0	3.0	3.0
0.80000	27	27	1.000	0.00830	0.20000	24.0	21.2	3.0	3.0
0.80000	30	30	1.000	0.00830	0.20000	24.0	21.3	3.0	3.0
0.80000	6	6	1.000	0.00830	0.20000	27.0	21.0	3.0	3.0
0.80000	9	9	1.000	0.00830	0.20000	27.0	22.1	3.0	3.0
0.80000	12	12	1.000	0.00830	0.20000	27.0	22.7	3.0	3.0
0.80000	15	15	1.000	0.00830	0.20000	27.0	23.2	3.0	3.0
0.80000	18	18	1.000	0.00830	0.20000	27.0	23.5	3.0	3.0

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80000	21	21	1.000	0.00830	0.20000	27.0	23.8	3.0	3.0
0.80000	24	24	1.000	0.00830	0.20000	27.0	24.0	3.0	3.0
0.80000	27	27	1.000	0.00830	0.20000	27.0	24.2	3.0	3.0
0.80000	30	30	1.000	0.00830	0.20000	27.0	24.3	3.0	3.0

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

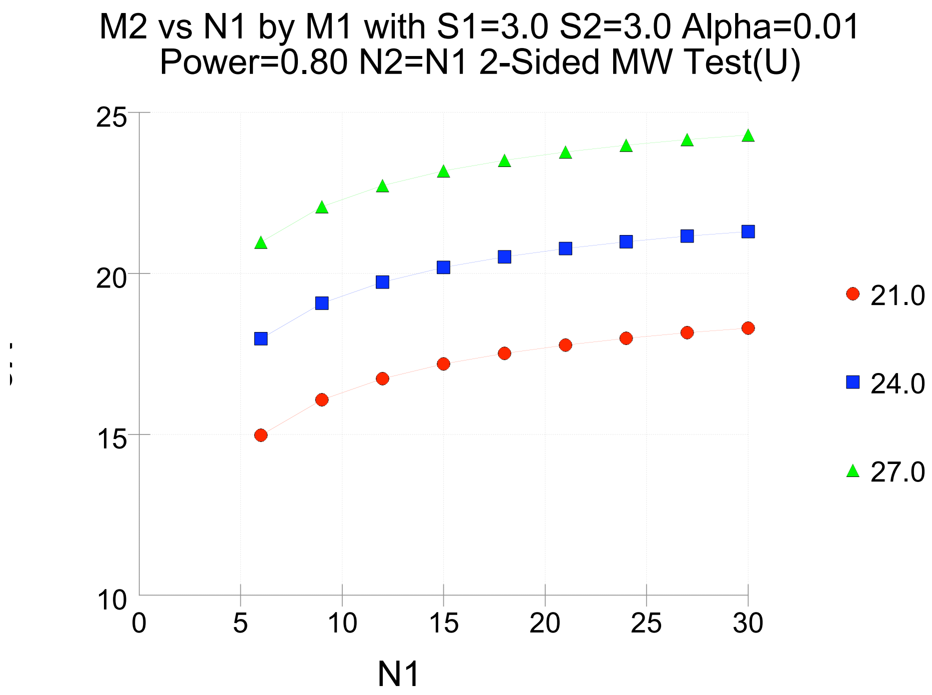
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 6 and 6 achieve 80% power to detect a difference of 6.0 between the null hypothesis that both group means are 21.0 and the alternative hypothesis that the mean of group 2 is 15.0 with known group standard deviations of 3.0 and 3.0 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Appendix 2 Representative periapical radiographs

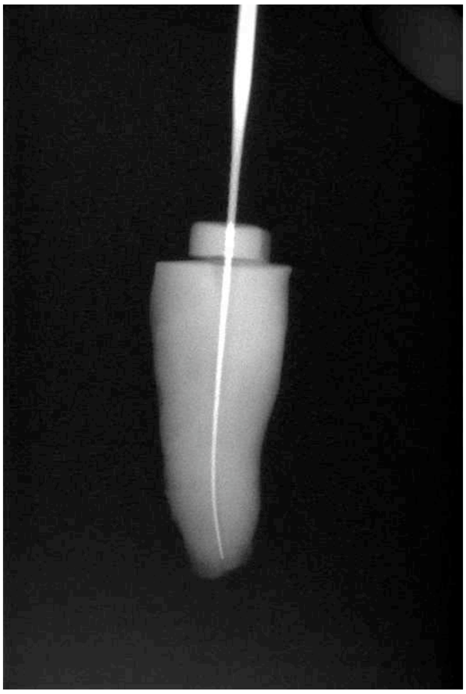
Teeth were assessed for inclusion into the Study by digital radiographic screening (the digital radiographic unit was Sirona Heliodent DS, D3334 and D3302, Sirona Dental Systems GmbH, Bensheim, Germany; and digital radiographic software was Sidexis Next Generation V 1.2, Sirona Dental Systems GmbH, Germany). The screening radiographic examination involved taking two periapical radiographs, one from the buccolingual view and one from the mesiodistal view.

Teeth were finally excluded if they did not have a single patent canal; simple root canal anatomy; uncomplicated apical anatomy; only a single mild root canal curvature; and suitable working length.

The following periapical radiographs are representative of the Study Sample.

Figure 24 Representative digital periapical radiographs of specimen 11, Group 1: a) the buccolingual view; and b) the mesiodistal view

a)



b)

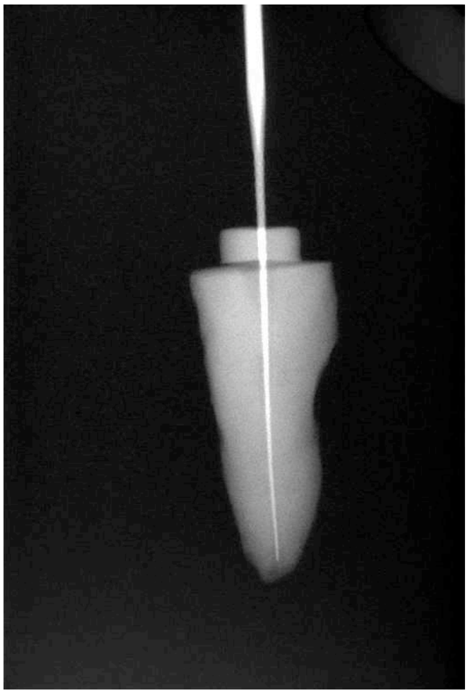


Figure 25 Representative digital periapical radiographs of specimen 32, Group 1: a) the buccolingual view; and b) the mesiodistal view

a) b)

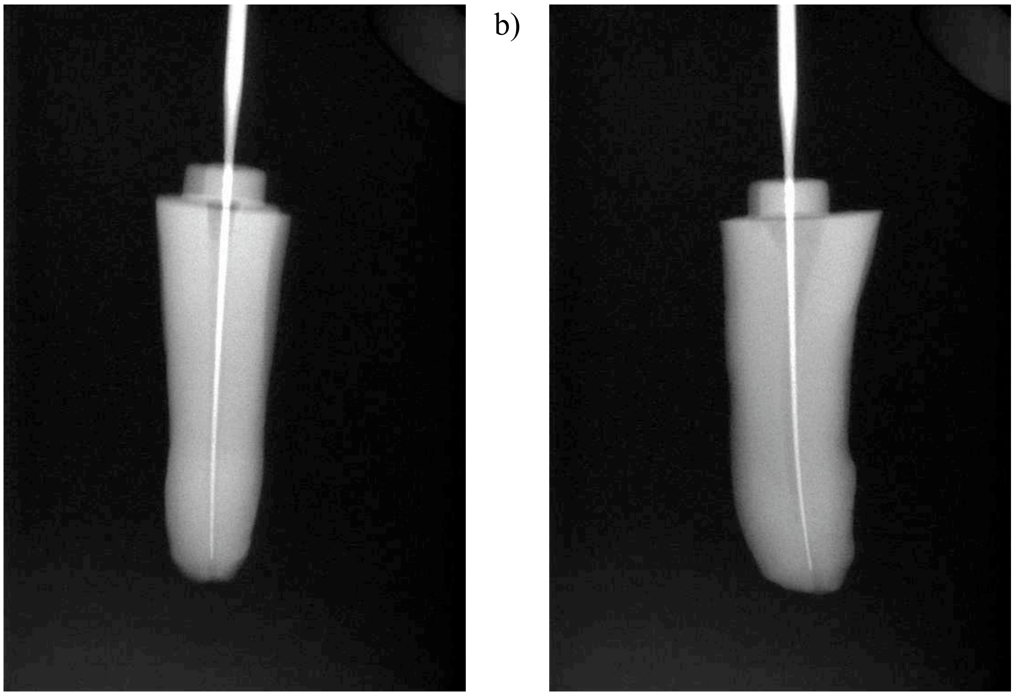


Figure 26 Representative digital periapical radiographs of specimen 85, Group 1: a) the buccolingual view; and b) the mesiodistal view

a) b)

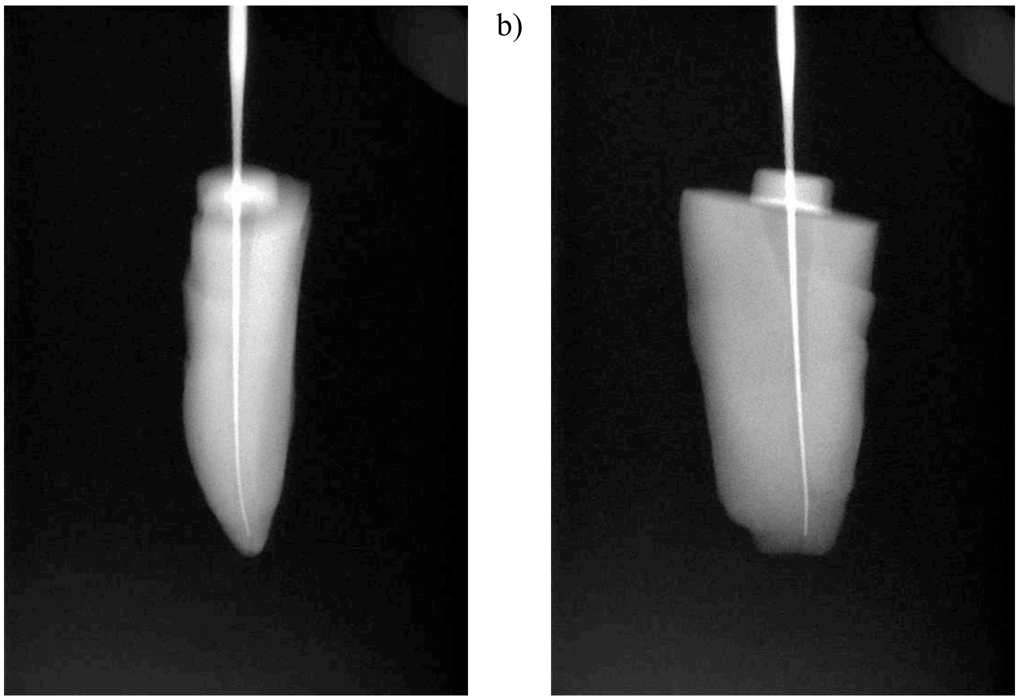


Figure 27 Representative digital periapical radiographs of specimen 158, Group 1: a) the buccolingual view; and b) the mesiodistal view

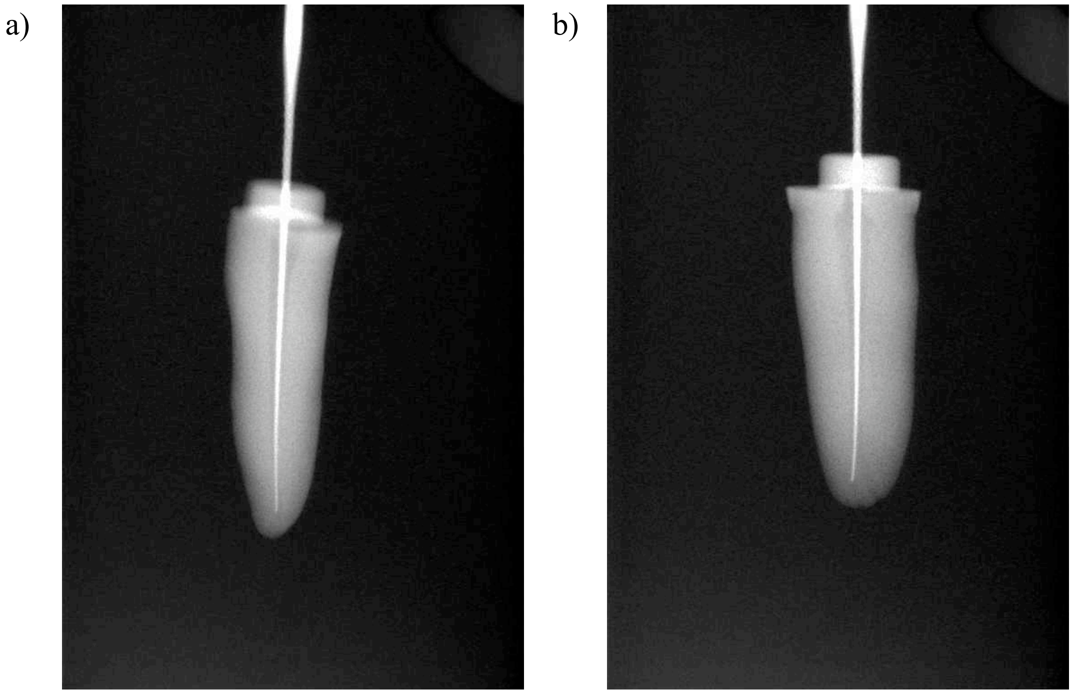


Figure 28 Representative digital periapical radiographs of specimen 34, Group 2: a) the buccolingual view; and b) the mesiodistal view

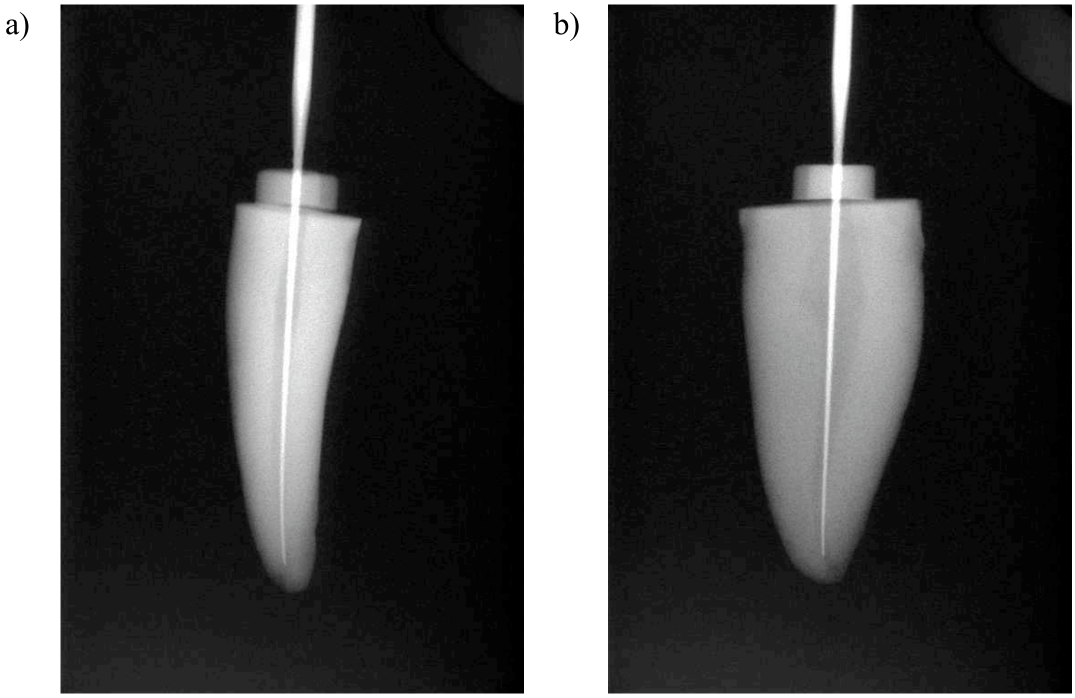


Figure 29 Representative digital periapical radiographs of specimen 59, Group 2: a) the buccolingual view; and b) the mesiodistal view

a) b)

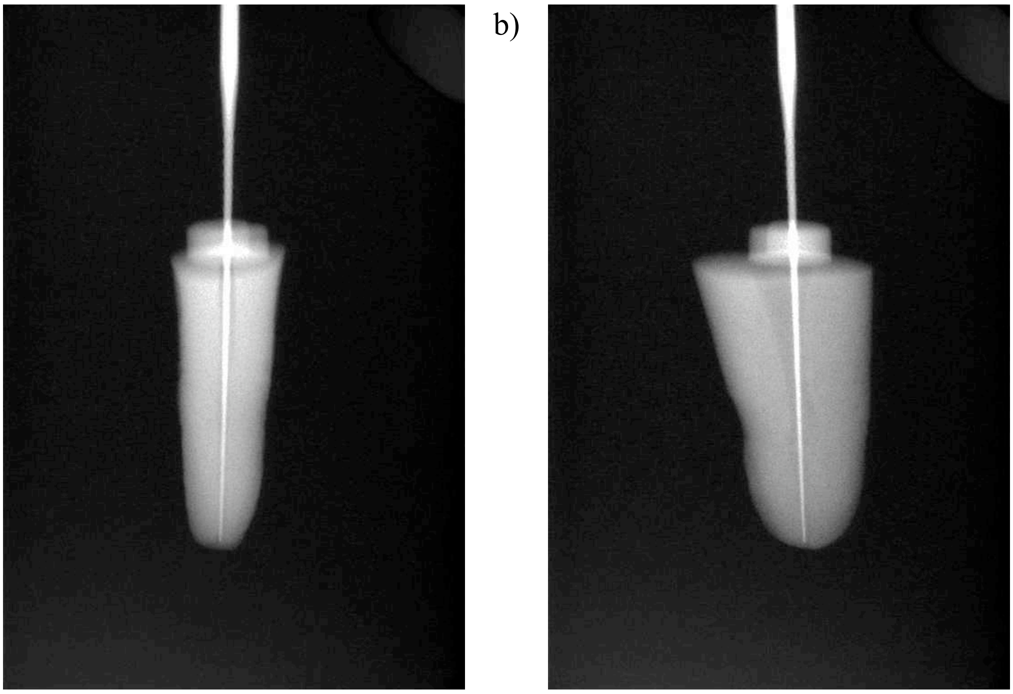


Figure 30 Representative digital periapical radiographs of specimen 113, Group 2: a) the buccolingual view; and b) the mesiodistal view

a) b)

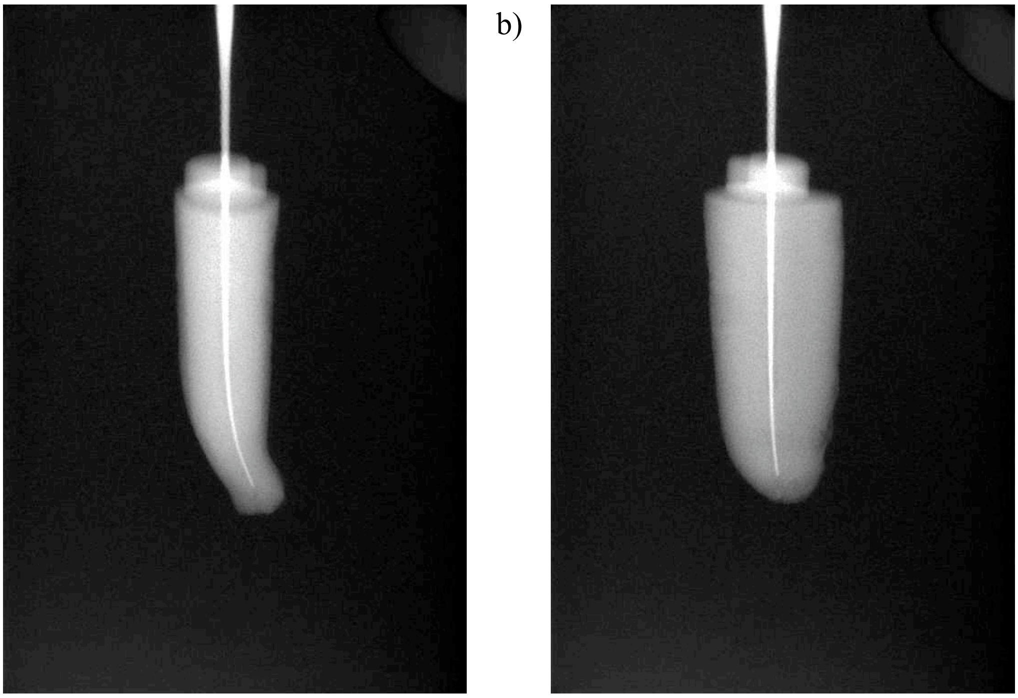
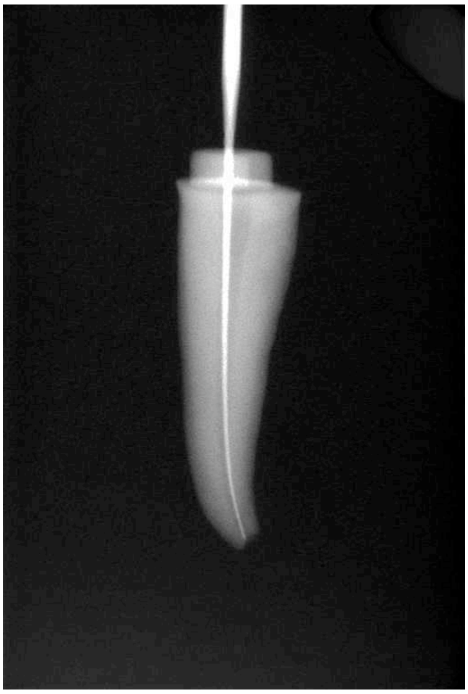


Figure 31 Representative digital periapical radiographs of specimen 132, Group 2: a) the buccolingual view; and b) the mesiodistal view

a)



b)

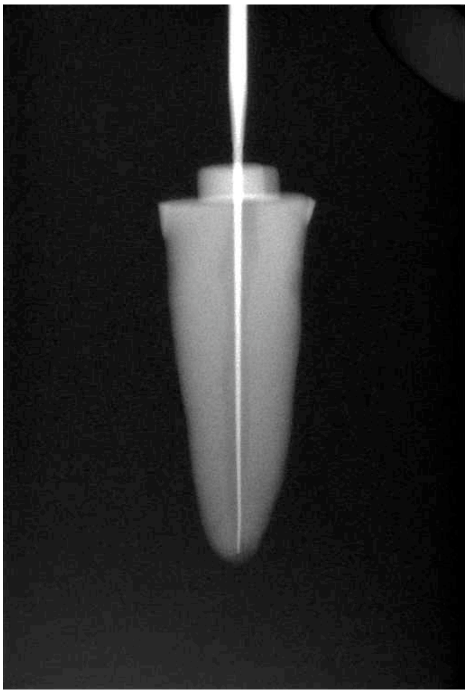
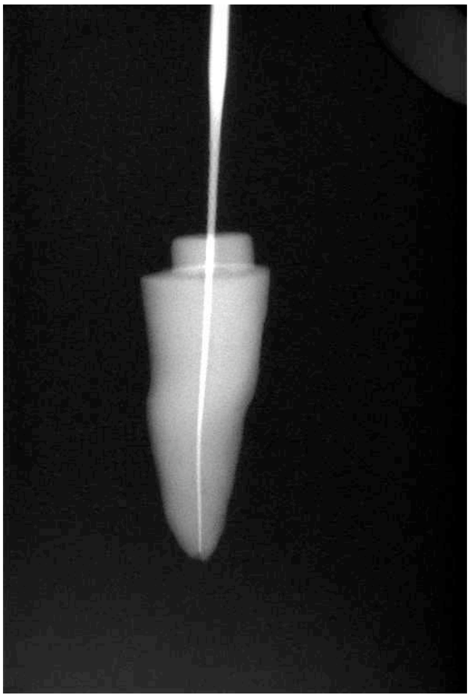


Figure 32 Representative digital periapical radiographs of specimen 21, Group 3: a) the buccolingual view; and b) the mesiodistal view

a)



b)

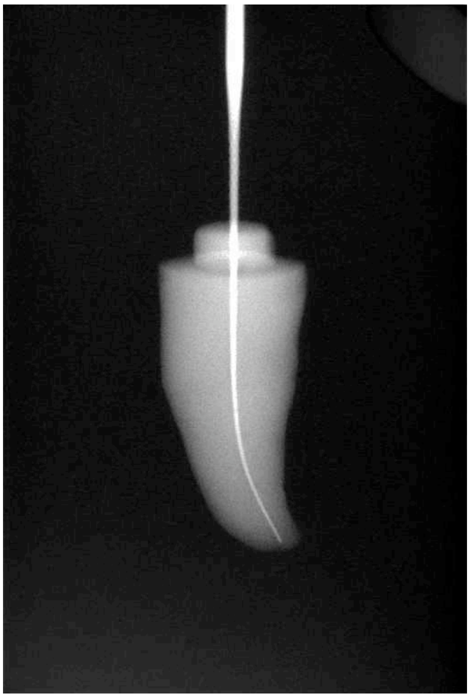
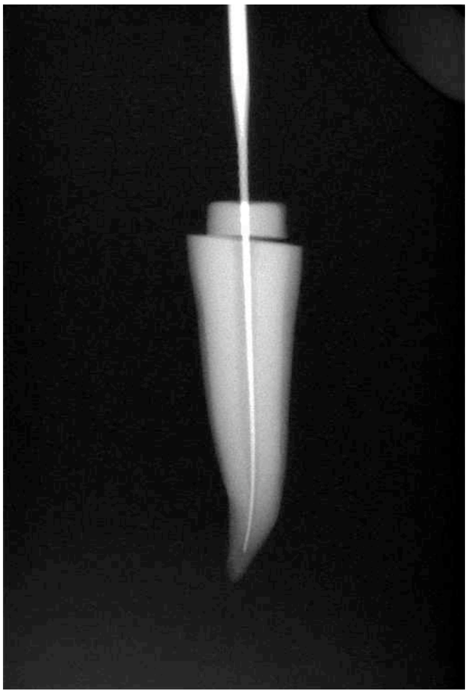


Figure 33 Representative digital periapical radiographs of specimen 29, Group 3: a) the buccolingual view; and b) the mesiodistal view

a)



b)

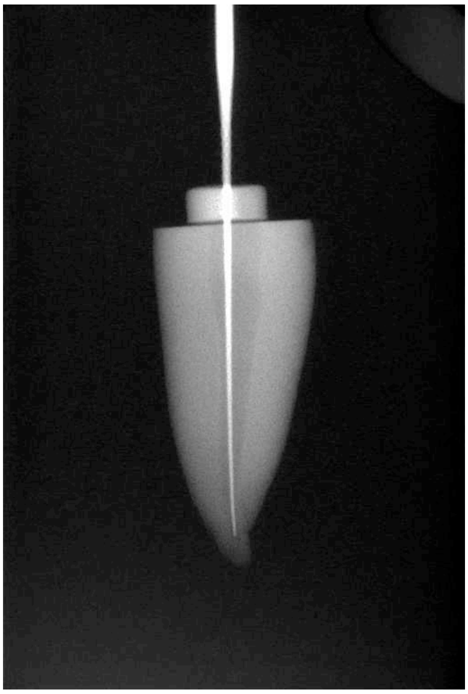
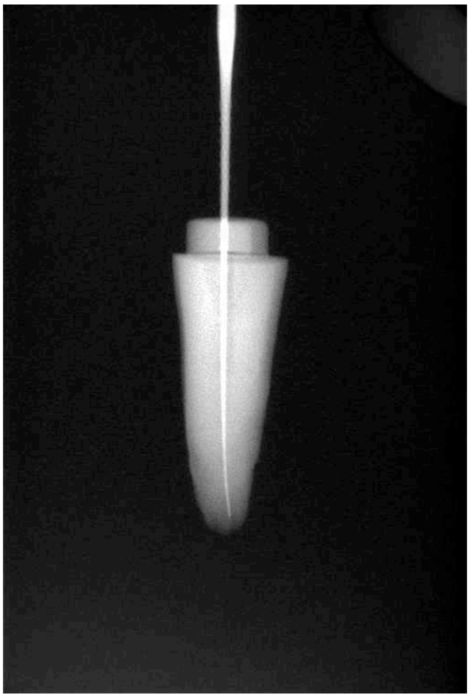


Figure 34 Representative digital periapical radiographs of specimen 92, Group 3: a) the buccolingual view; and b) the mesiodistal view

a)



b)

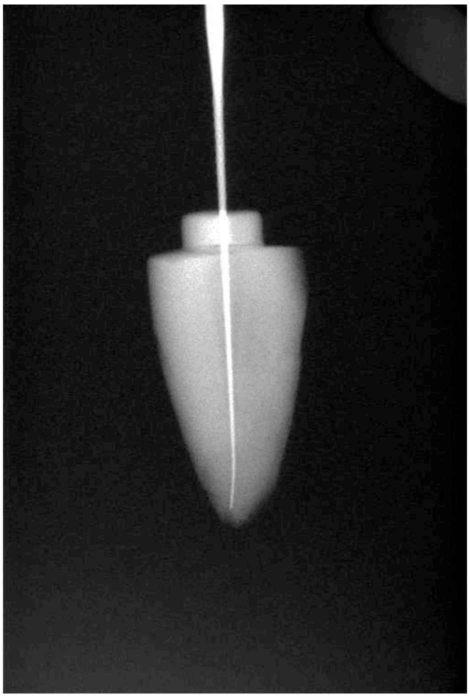


Figure 35 Representative digital periapical radiographs of specimen 126, Group 3: a) the buccolingual view; and b) the mesiodistal view

a) b)

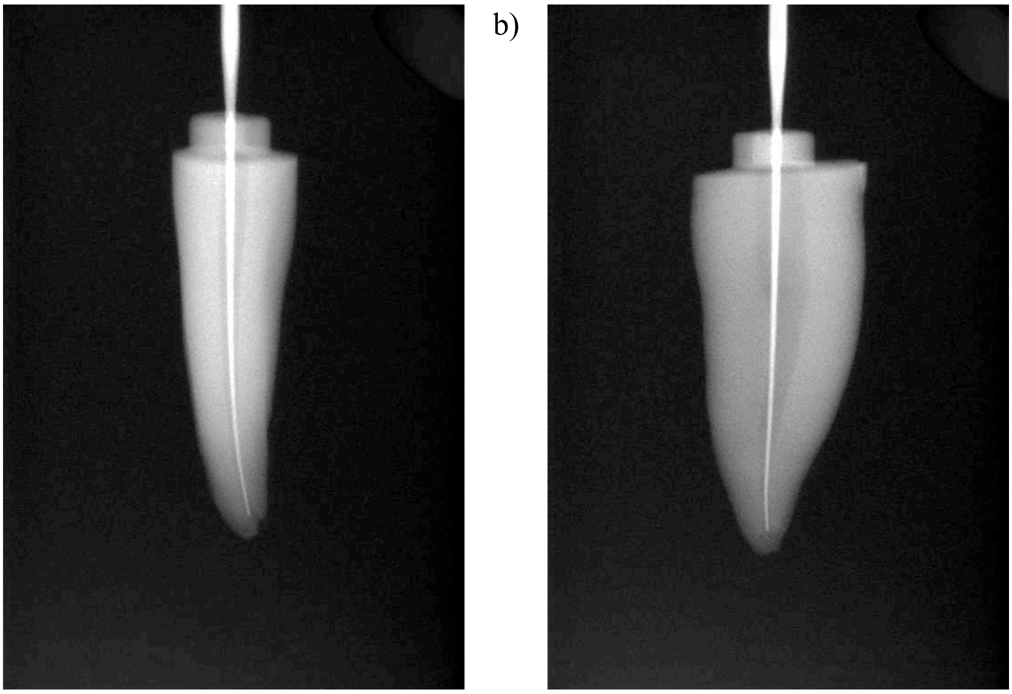


Figure 36 Representative digital periapical radiographs of specimen 30, Group 4: a) the buccolingual view; and b) the mesiodistal view

a) b)

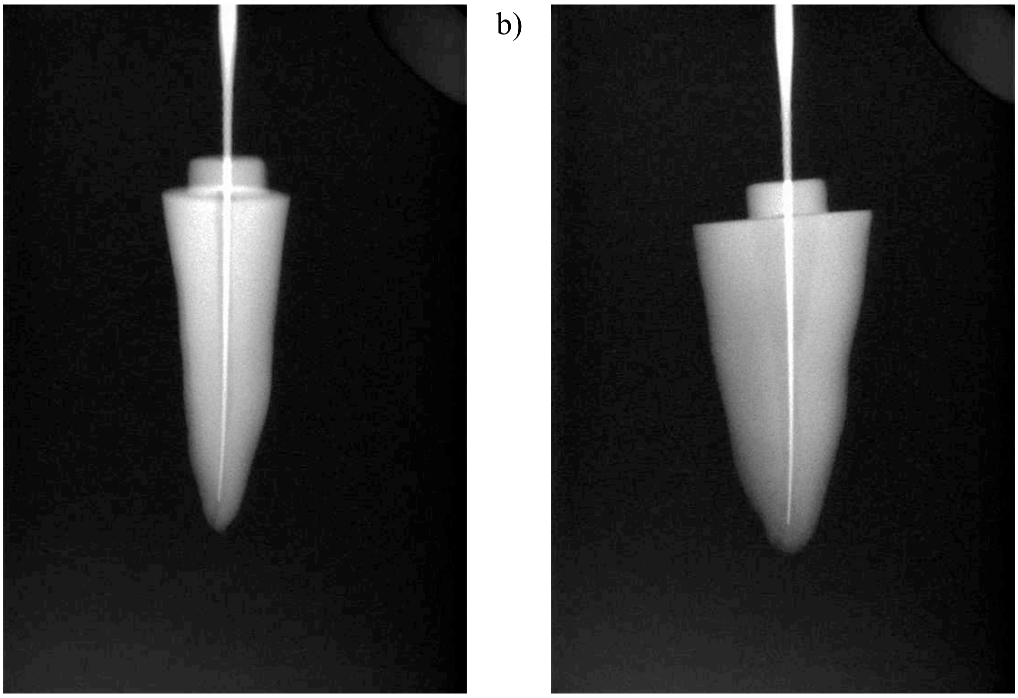
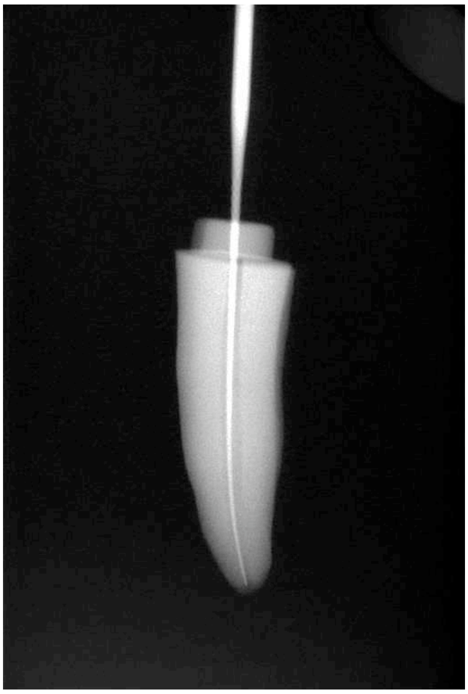


Figure 37 Representative digital periapical radiographs of specimen 36, Group 4: a) the buccolingual view; and b) the mesiodistal view

a)



b)

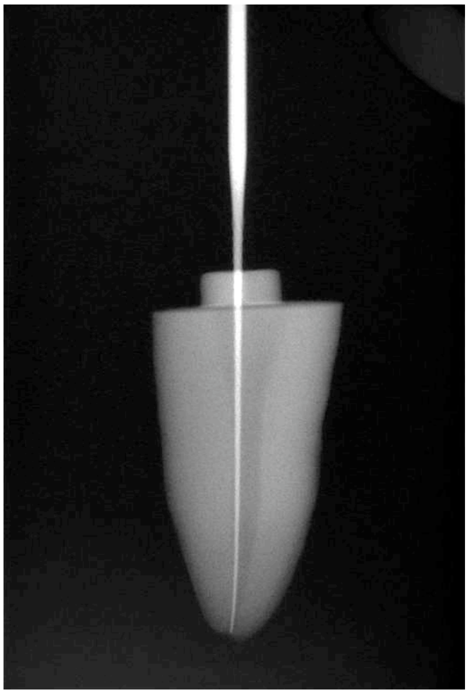
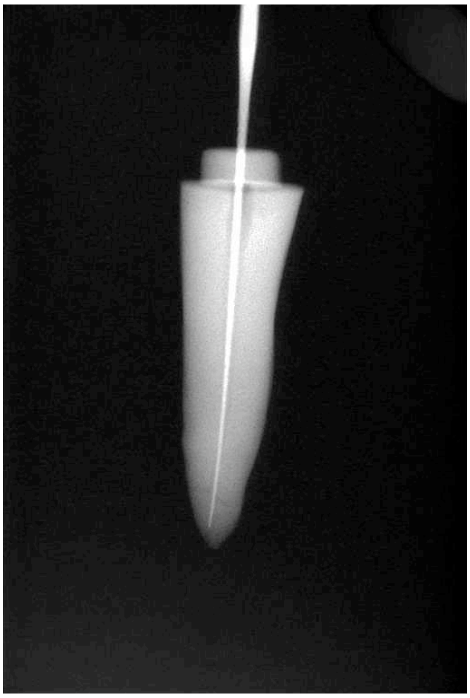


Figure 38 Representative digital periapical radiographs of specimen 57, Group 4: a) the buccolingual view; and b) the mesiodistal view

a)



b)

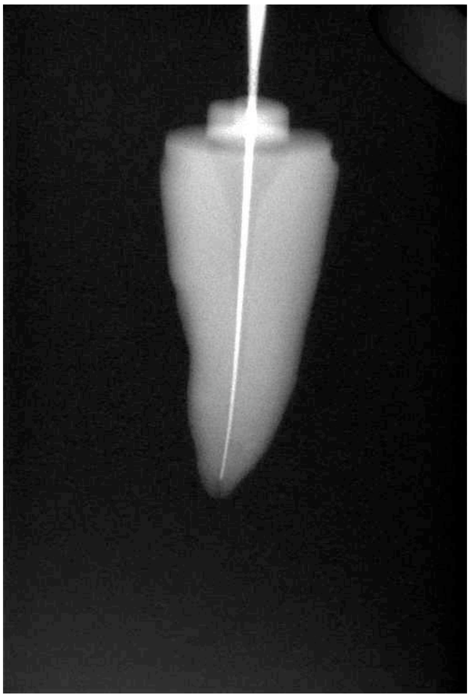
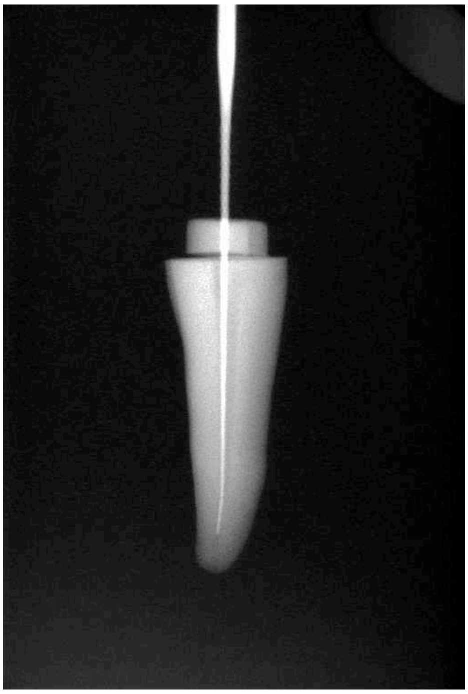


Figure 39 Representative digital periapical radiographs of specimen 89, Group 4: a) the buccolingual view; and b) the mesiodistal view

a)



b)

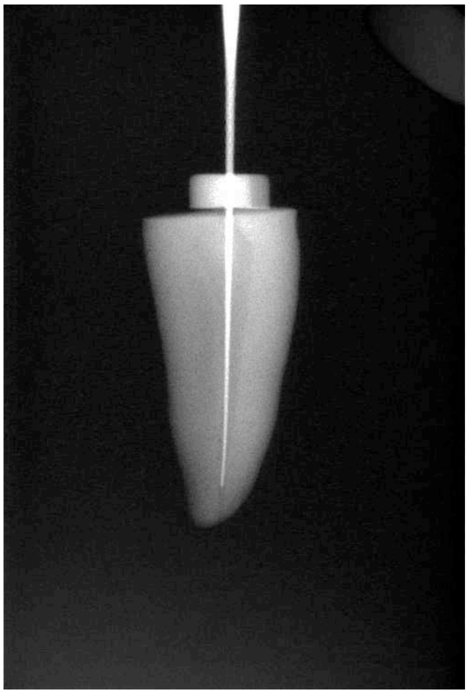
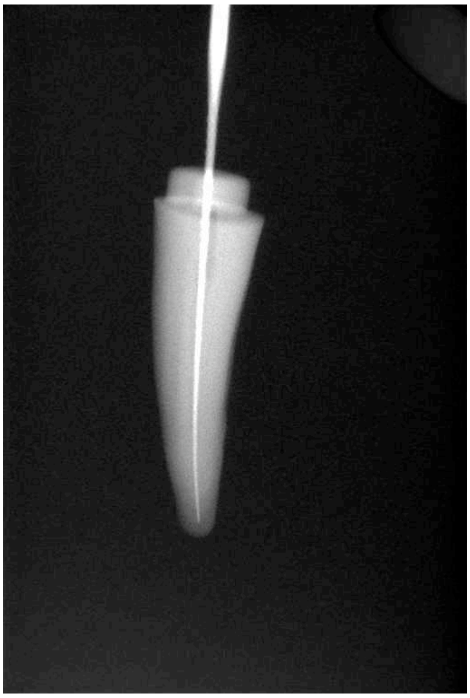
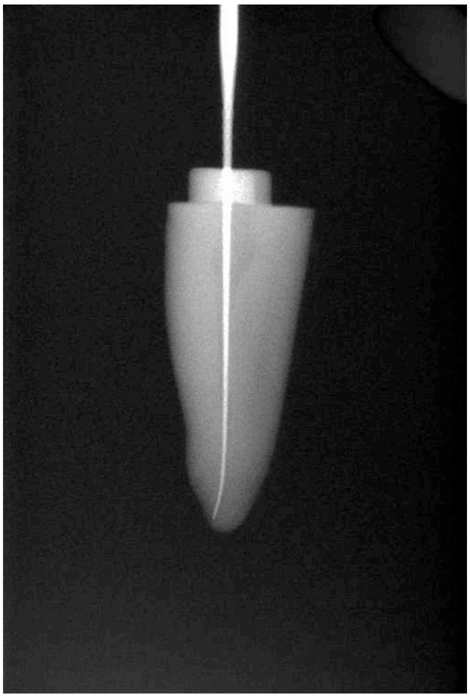


Figure 40 Representative digital periapical radiographs of specimen 151, Group 4: a) the buccolingual view; and b) the mesiodistal view

a)



b)



Appendix 3 Er,Cr:YSGG endodontic protocol

Er,Cr:YSGG laser (Waterlase™, Millennium, Biolase Technology Inc, San Clemente, CA, USA) was used as recommended by the manufacturer.[1-5] Most of the detail of this protocol was obtained directly from lectures given by Chen in 2003.[1]

Root canal preparation technique

In summary:

1. Glide path establishment: enlarge apex to a size 25 K-type file.
2. Root canal debridement:
    a. Z2 (200µm);
    b. use 1-2mm short of working length (allow for optimum ablation distance), mark tip with indelible pen;
    c. aim tip at side of root canal;
    d. place tip; activate tip and ablate as the tip is withdrawn; over 8sec;
    e. sweeping motion;
    f. replace tip and aim at different part of the root canal, repeat e; and
    g. repeat d-e, a total of 6 times, simulating a circumferential filing concept.
3. Root canal shaping: use Z3 (320µm) as in 2; use Z4 (400µm) as in 2; enlarge root canal until a size 35 K-type file fits easily to working length; may use Gates-Glidden bur to flare coronal 2 thirds
4. Saline irrigation was used in copious quantities.

Waterlase™ YSGG parameters[1]

Procedure	Tip	Power (W)	Water (%)	Air (%)
RC debridement	Z2 (200µm)	1.5 (<2.5)	24	34
RC shaping	Z3 (320µm)	1.5 (<2.5)	24	34
RC shaping	Z4 (400µm)	1.5 (<2.5)	24	34
RC smear/bactericidal	Z2 (200µm)	1	24	34
RC smear/bactericidal	Z3 (320µm)	1	24	34

Note: Optimum ablation is 1-1.5mm from the tip; recommended use G6 (600µm) in up to 80 teeth; recommended use Z series tips in 5-10 teeth; use Z series tips <2.5W reduces risk of root perforation

Anterior tooth RCT

1. Access G6: (600µm) tip
2. Pulpectomy: G6 (600µm); in vital roots use Z2 to path find to ≈1/2 estimated working length; ablate as tip progresses apical to desensitise pulp tissue
3. Working length determination: apex locator or radiograph; a size 15 K-type file
4. Glide path establishment: enlarge apex to a size 25 K-type file

5. Root canal debridement: Z2 (200µm); use 1-2mm short of working length (allow for optimum ablation distance), mark tip with indelible pen; aim tip at side of root canal; place tip; activate tip and ablate as the tip is withdrawn; over 8sec; sweeping motion; replace tip and aim at different part of the root canal, repeat e; repeat d-e, a total of 6 times, simulating a circumferential filing concept
6. Root canal shaping: use Z3 (320µm) as in 5; use Z4 (400µm) as in 5; enlarge root canal until a 35 K-type file fits easily to working length; may use Gates-Glidden bur to flare coronal 2 thirds
7. Obturation: personal preference; WHC uses Schilder's warm vertical condensation technique

Molar RCT

1. Use LA
2. RCT by preferred conventional tech (eg WHC uses Gates-Glidden bur, profile) until apex finished to a size 35 K-type file
3. Use Waterlase™ to remove smear and bactericidal effect only
4. Z tips used to working length minus 2-3mm
5. Z2 ablate on withdrawal, over 8sec, 4 times
6. Z3 over 8sec, 3 times
7. Conservative approach because of root canal curvature and risk of perforation

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2. Chen WH. YSGG laser root canal therapy. Dent Today 2002;21:74-77.

3. Biolase(TM). Clinical articles. URL: 'www.biolase.com/clinical.html'. Accessed 6 Oct 2004.

4. Chen WH. Er,Cr:YSGG laser root canal procedure: case report. Endodontic Therapy 2002;

5. Jesse J. Complete root canal therapy using the Waterlase YSGG all-tissue dental laser. Dental Products Report 2002;

1. Chen WH. Er,Cr:YSGG Laser: one wavelength for both hard and soft tissue applications. Lasers in dentistry seminar. Brisbane2003.

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Appendix 4 Er:YAG experimental root canal preparation protocol

Key Laser® 3 experimental root canal preparation technique

Key Laser® 3 (KEY Laser 1242, KaVo Dental GmbH, Jena Germany) experimental root canal preparation technique was based on the following previously described techniques:

1. The crown-down pressureless technique was first described by Morgan. [1]
2. Roane et al [2] first described this technique and its rationale, developed by trial and error experimentation over 12yr.[2] Evidence suggests that root canals prepared with this method tend to stay more centred in the canal during preparation with less transportation even using larger files in the apical portion of curved canals.[3]
3. Double flared technique was a modification of the flared preparation especially indicated for teeth with necrotic or gangrenous pulps. In addition to the advantages of the flared technique, the double flared technique was claimed to further reduce the potential of apical debris extrusion.[4]

Objective

The objectives of this coronal-apical technique were to:

1. Produce early coronal flaring with special emphasis on reducing apical extrusion of debris. It was postulated that "early flaring of the canal walls would lessen the potential for a positive apically directed hydrostatic pressure by the establishment of an adequate coronal escape way."[4]
2. Facilitate preparation of curved canals without causing deviation or zipping.[1]

Technique

Early radicular access through preparing the coronal two-thirds of the root canal removes the bulk of the canal contents and facilitates straight-line access to the apical third of the canal. Note that no pre-curving of files was performed and apical pressures were avoided. Replacing and rotating an instrument of the same size at the same depth was also avoided to prevent ledging in curved canals.[1]

FlexoFiles® (Dentsply Maillefer, Dentsply International Inc, Tulsa, Oklahoma, USA) were used with the balanced force technique,[2] these files were flexible stainless steel files with a modified non-cutting tip to reduce apical transportation. The files were not pre-curved prior to insertion and placement into the root canal was accomplished using 90º (<180º) clockwise rotation and light inward pressure to engage to the canal wall (power phase). Cutting was accomplished using ≥120º anti-clockwise rotation and inward pressure (control phase), while debris removal was carried out using outward pull clockwise rotations.[2]

In summary:

1. Scout the coronal 2 thirds of the canal with hand files.[5, 6]
    a. Determine radicular access length to a depth to which a size 30 K-type file penetrates to its point of first resistance. The coronal portion of the canal should be prepared to this length.[1]
    b. Copious irrigation with EDTAC.[7]

2. Pre-enlargement of the coronal 2 thirds, use #1, #2 and #3 band fibre tips.[5, 6]
    a. Straight line access with 50/10 fibre tip.
    b. Radicular access preparation by using a #1 band fibre tip, followed by a #2 and then #3 band fibre tip, taken to the radicular access length without any apical force.[1]
    c. Copious irrigation with NaOCl.[7]
3. Scout the apical 1 third of the canal.[5, 6]
    a. Confirm working length and verify the glide path with hand files.[5, 6]
    b. Confirm working length using a size 15 K-type file and periapical radiographic confirmation.
    c. Place a size 30 K-type file into the canal until it encounters resistance. Use Balanced Force technique. Repeat using a size 25 K-type file and then successively smaller files until the working length was reached.[1]
    d. This completes the first instrumentation sequence, which began with a size 30 K-type file at the radicular access length and finish with the largest file that passively reached the working length.[1]
    e. A second instrumentation sequence begins with a file one size larger than the file that began the previous sequence (i.e. a size 35 K-type file). This was used with Balanced Force technique and successively smaller files inserted and similarly rotated until the working length was reached. The file at the apical seat should be a size larger than in the first sequence.
    f. Further sequences of instrumentation were performed until the apical file was a minimum of a size 30 K-type file.
    g. Copious irrigation with NaOCl.[7]
4. Finish the apical 1 third preparation, use #1, #2 and #3 band fibre tips.[5, 6]
    a. Finish with a 0.10 taper as suggested in Balanced Force technique.[2] Step back with 1mm increments between successively larger fibre tips.
    b. Preparation of the apical third of the canal to the appropriate size using the step-back technique means that there was much less filing was necessary to establish the final taper. Once again, the use of recapitulation was stressed.[4]
    c. Copious irrigation with EDTAC.[7]
5. Gauge the diameter of the foremen to confirm completion of canal preparation.[5, 6]
6. Refine the apical 1 third preparation as indicated, (#2 and #3 band fibre tips if indicated).
7. Final rinse with EDTAC.[7]

Advantages

The main advantages of the crown-down pressureless technique were: early coronal access reduces apical extrusion of debris[8]; early access for irrigants; early removal of cervical dentine interferences and reduction of canal curvatures promote tactile awareness in apical third of the canal; straight line access developed; by all accounts the rotary use of non-pre-

curved files avoids apical zipping; and working length was less likely to change during apical instrumentation because canal curvature has been reduced before working length was actually established.[1]

The primary advantages of the balanced force technique include: the ability to use of larger files in the apical portion of curved canals than would be possible using the normal push-pull filing action; there was less potential for canal transportation; and the potential for ledging and perforation was less due to the use of the Flex-R files and their non-cutting file tips.[2]

The advantages of the double flared technique include: greater taper in the cervical and middle thirds of the root, thus the removal of canal contents was more effective and the root canal was better cleansed; allow early access of irrigants to the pulp chamber and the coronal root canal; early flaring prevents the potential of forcing debris through the apex; micro-organisms and necrotic pulp were removed in the initial phase, decreasing the probability of carrying them to the apex and produce an exacerbation; and it was claimed that stresses that were induced during lateral condensation were more evenly distributed throughout the root when it was prepared with the flared technique [4]

Disadvantages

The main disadvantages include: no pre-curved files were used so preparation in severely curved canals could be difficult; the continual repetition of file waves was time consuming; this technique was not suitable for moderate to severe curvatures; the risk of separating stainless steel instruments when rotating in a curved canal was great; and this technique uses rotary cutting motion and without the use of appropriate irrigants the canals may not be as clean as in those prepared by techniques using circumferential filing.[1]

There was the theoretical risk of instrument fracture because the files were used with a rotational action. Furthermore the use of triangular cross-section files and the use of apical pressure with anti-clockwise rotation increase this risk of fracture. This risk should be minimised if the files were not over rotated/worked.[2]

The disadvantages of the double flared technique include: this technique was indicated only for straight root canals or in the straight portions of curved canals; this technique was not indicated for calcified canals, young permanent teeth, or teeth with opened apex due to the thin root dentine thickness; the sequence of filing was time consuming; and there was a risk of over-instrumentation [4]

Key Laser® 3 parameters

Used with endodontic handpiece 2062

Fibre insert	Diameter (mm)	Length (mm)	Energy (mJ)	Frequency (Hz)	Air	Water
#1 band, 30/28	0.285	28	500	4	Y	N
#2 band, 40/28	0.375	28	450	4	Y	N
#3 band, 50/28	0.470	28	450	4	Y	N
#3 band, 50/10	0.470	10	500	4	Y	N

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2. Roane JB, Sabala CL, Duncanson MG, Jr. The "balanced force" concept for instrumentation of curved canals. J Endod 1985;11:203-211.

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4. Fava LR. The double-flared technique: an alternative for biomechanical preparation. J Endod 1983;9:76-80.

5. Ruddle CJ. Current concepts for preparing the root canal system. Dent Today 2001;20:76-83.

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7. Abbott PV, Heijkoop PS, Cardaci SC, Hume WR, Heithersay GS. An SEM study of the effects of different irrigation sequences and ultrasonics. Int Endod J 1991;24:308-316.

8. al-Omari MA, Dummer PM. Canal blockage and debris extrusion with eight preparation techniques. J Endod 1995;21:154-158.

1. Morgan LF, Montgomery S. An evaluation of the crown-down pressureless technique. J Endod 1984;10:491-498.

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8. al-Omari MA, Dummer PM. Canal blockage and debris extrusion with eight preparation techniques. J Endod 1995;21:154-158.

Appendix 5 Definitions of assessment criteria

Study 1 assessment criteria definitions

Criteria	Score	Character	Definition
Debris (dentine chips, pulp remnants, and particles loosely attached to the canal wall) [1, 2]	1	Clean (<5%)	Clean canal wall, only very few debris particles
	0	Cover >5%	E.g. few small conglomerations, many conglomerations, or complete or nearly complete covering
Smoothness[3, 4]	1	Good	Smoothness and regularity
	0	Poor	Roughness and irregularity
Apical stop[3-6]	2	Well defined	
	1	Poorly defined	
	0	Absent	
Apical zip[7]	1	Absent	An irregular widened area created by the MAF near the end-point of the preparation where dentin had been removed excessively from the outer aspect of the canal
	0	Present	
Flow[3, 4]	1	Good	A continuous blending of the canal from orifice to apical stop
	0	Poor	Abrupt changes in direction and the presence of ledges
Taper[3, 4]	1	Good	Canal had a conical shape throughout its length
	0	Poor	Hourglass or cylindrical shapes
Elbows[7]	1	Absent	Occurred concurrently with an apical zip and formed a narrower region, more coronally
	0	Present	
Ledges[7]	1	Absent	An irregular area of dentin was removed from the outer aspect of the curved porion of the canal not associated with preparation the end-point. Ledges were always associated with a narrow region more coronally.
	0	Present	
Perforations[7]	1	Absent	Occurred as separate and distinct false canals towards the end-point, along the outer aspect of the curve not confluent with the original canal
	0	Present	

Study 1 assessment score sheet

The following sheet shows the design of the scoring sheet used by the evaluators when they scored the photomicrographs.

Root	Debris coronal 1/3		Smoothness coronal1/3		Debris mid 1/3		Smoothness mid 1/3		Debris apical 1/3		Smoothness apical 1/3		Apical stop			Apical zip		Flow		Taper		Elbows		Ledges		Perforations	
	Clean (<5%)	Cover >5%	Good	Poor	Clean (<5%)	Cover >5%	Good	Poor	Clean (<5%)	Cover >5%	Good	Poor	Well defined	Poorly defined	Absent	Absent	Present	Good	Poor	Good	Poor	Absent	Present	Absent	Present	Absent	Present
1	1	0	1	0	1	0	1	0	1	0	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Study 2 assessment criteria definitions

The criteria previously used by Hulsmann et al [1] was used to assess debris and smear layer. However, the score allocated to each definition was reversed so that the higher the score the smaller the amount of debris or smear layer present (Figures 1 and 2).[1]

Scoring of debris was performed using a 200x magnification.

Smear layer was scored under a 1000x magnification.

Criteria	Score	Definition [1]
Debris (dentine chips, pulp remnants, and particles loosely attached to the canal wall)	5	Clean canal wall, only very few debris particles
	4	Few small conglomerations
	3	Many conglomerations; less than 50% of the canal wall covered
	2	More than 50% of the canal wall covered
	1	Complete or nearly complete covering of the canal wall by debris
Smear layer (dentine particles, remnants of vital or necrotic pulp tissue, bacterial components, and retained irrigant)	5	No smear layer, orifice of dentinal tubules patent
	4	Small amount of smear layer, some open dentinal tubules
	3	Homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules
	2	The entire root-canal wall covered with a homogenous smear layer, no open dentinal tubules
	1	A thick, (non)homogenous smear layer covering the entire root-canal wall

Figure 41 Pictorial criteria based on Hulsmann et al [1] that was used for assessing the amount of debris present: A, debris score 5, clean canal wall, only very few debris particles; B, debris score 4, few small conglomerations; C, debris score 3, many conglomerations; less than 50% of the canal wall covered; D, debris score 2, more than 50% of the canal wall covered; E, debris score 1, complete or nearly complete covering of the canal wall by debris

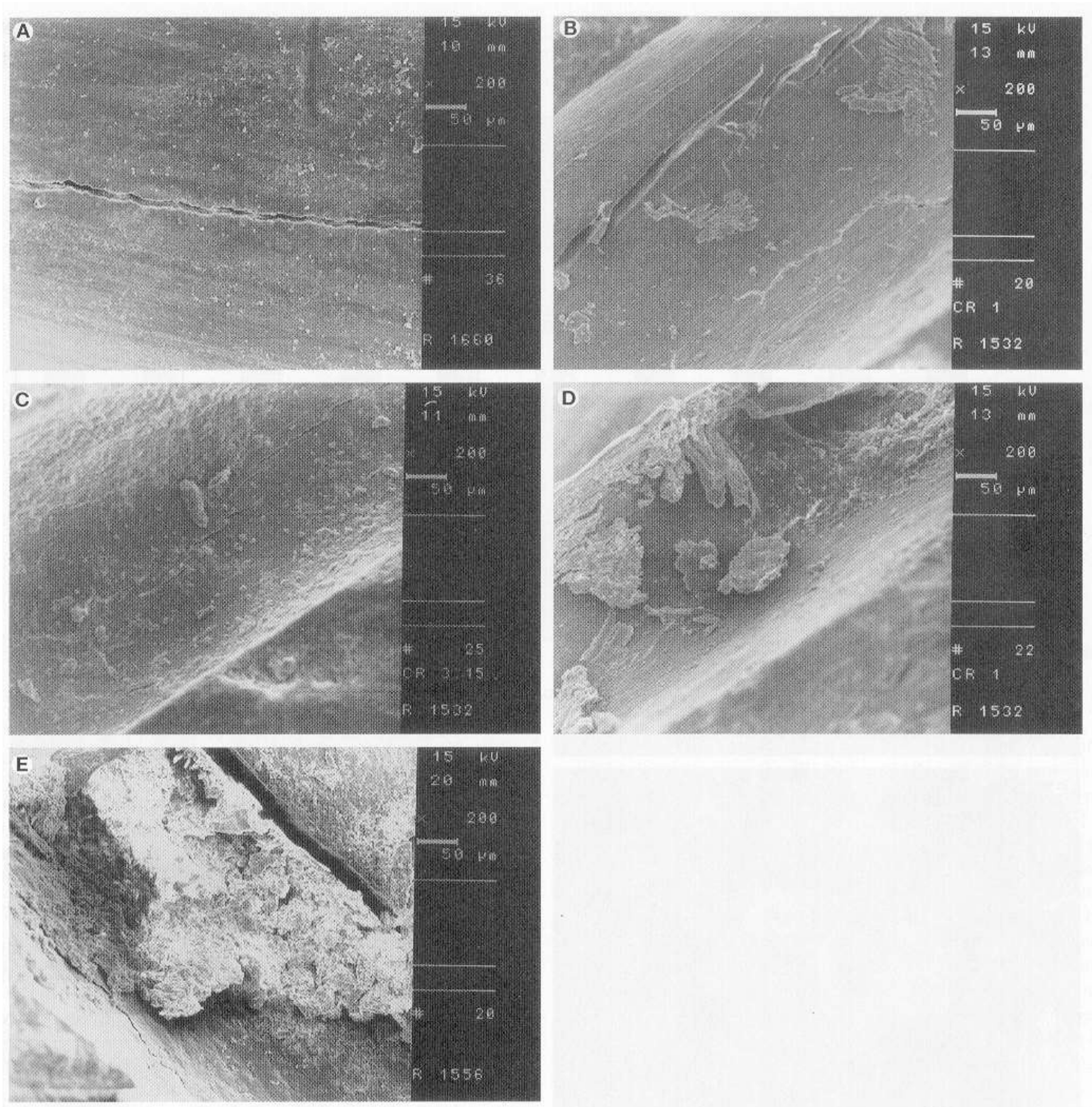
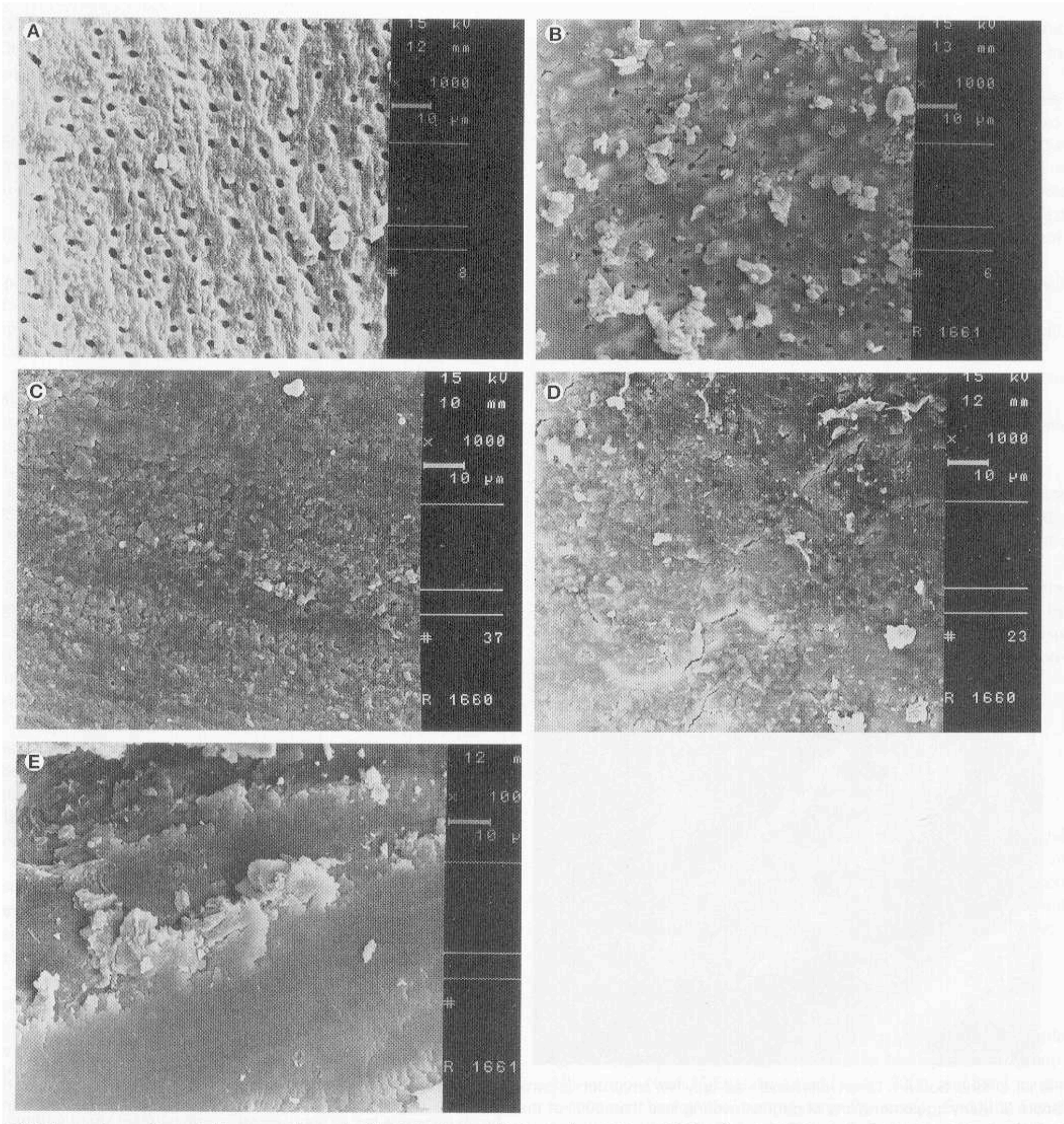


Figure 42 Pictorial criteria based on Hulsmann et al [1] that was used for assessing the amount of smear layer present: A, smear layer score 5, no smear layer, orifice of dentinal tubules patent; B, smear layer score 4, small amount of smear layer, some open dentinal tubules; C, smear layer score 3, homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules; D, smear layer score 2, the entire root-canal wall covered with a homogenous smear layer, no open dentinal tubules; E, smear layer score 1, a thick, (non)homogenous smear layer covering the entire root-canal wall



Study 2 assessment score sheet

The following sheet shows the design of the scoring sheet used the evaluators to score the SEM images.

Root	Sequence	Code	Debris coronal 1/3	Smear coronal /3	Debris mid 1/3	Smear mid 1/3	Debris apical 1/3	Smear apical 1/3
1	1	.						
3	2	…						
6	3	l.						
7	4	l..						
8	5	l…						
10	6	ll						

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2. Langeland K, Liao K, Pascon EA. Work-saving devices in endodontics: efficacy of sonic and ultrasonic techniques. J Endod 1985;11:499-510.

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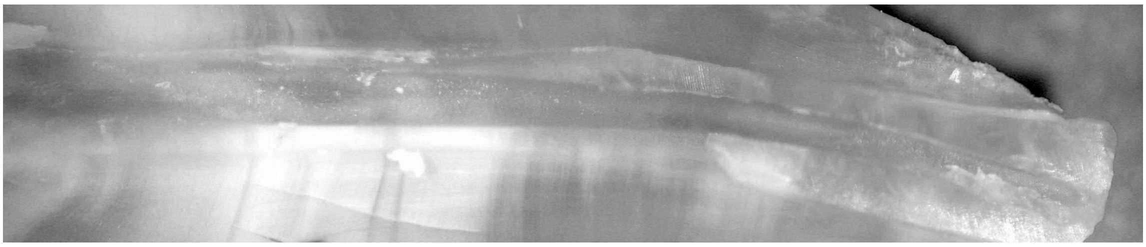
Appendix 6 Study 1 representative photomicrographs

Group 1, NiTi

Figure 43 Representative photomicrographs of a NiTi prepared Group 1 tooth (original magnification 30x, Specimen 11)



Coronal third Mid third Apical third

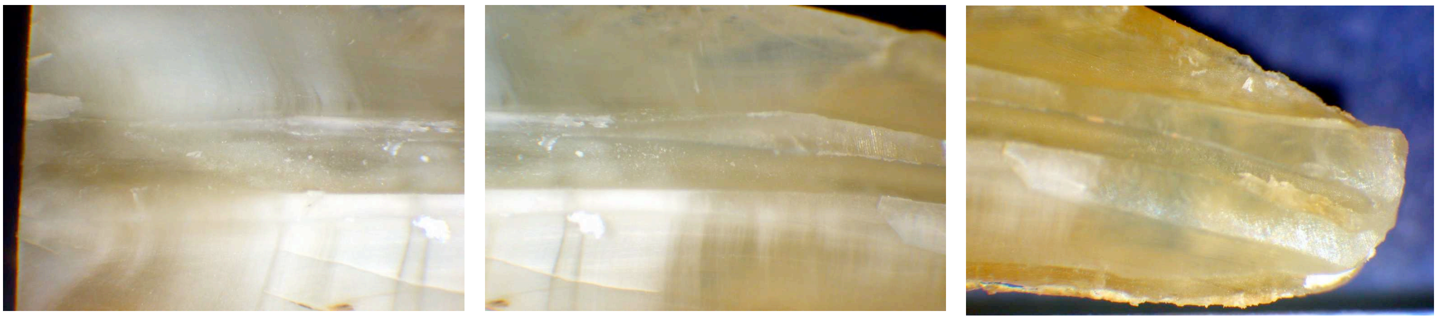
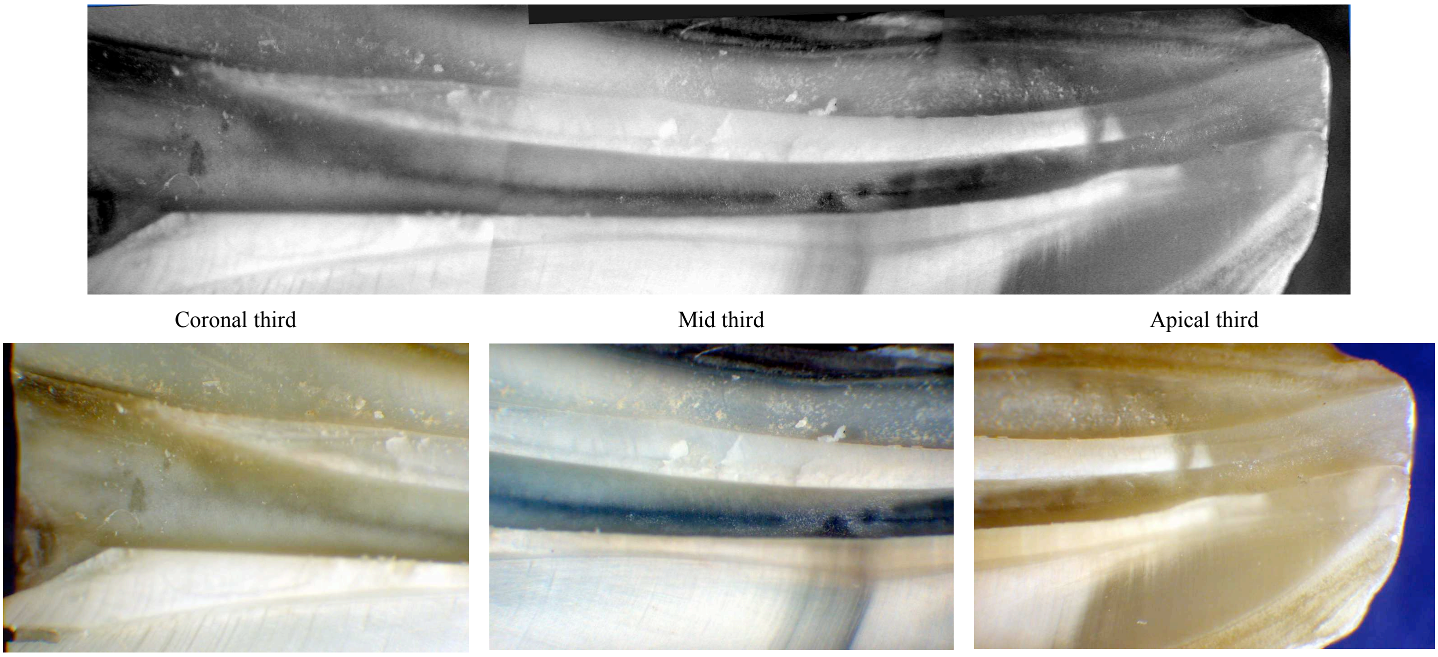
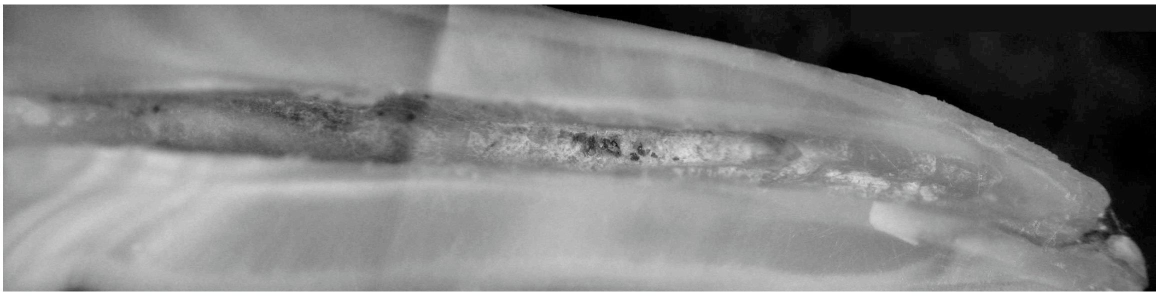


Figure 44 Representative photomicrographs of a NiTi prepared Group 1 tooth (original magnification 30x, Specimen 32)

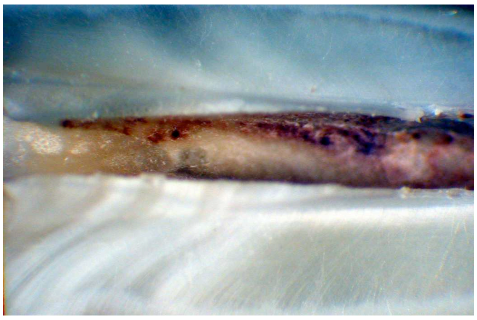


Group 2, Er:YAG

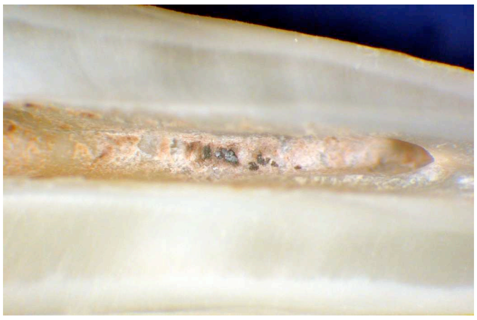
Figure 45   Representative photomicrographs of an Er:YAG prepared Group 2 tooth (original magnification 30x, Specimen 34)



Coronal third



Mid third



Apical third

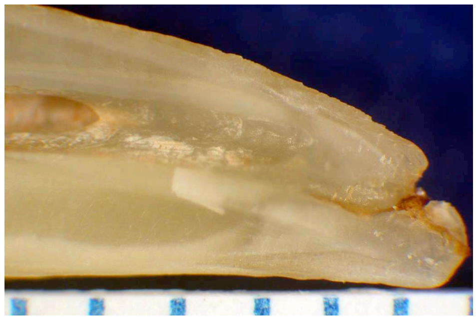
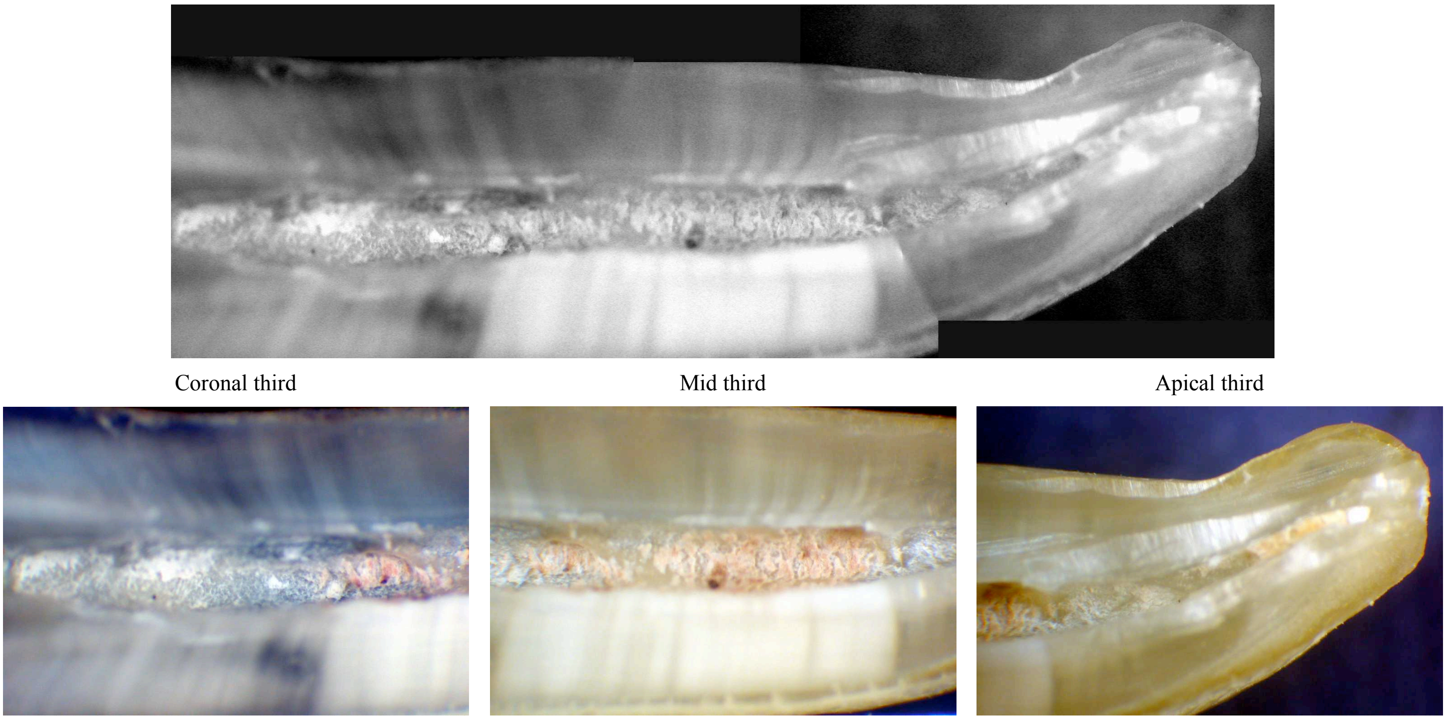


Figure 46 Representative photomicrographs of an Er:YAG prepared Group 2 tooth (original magnification 30x, Specimen 113)



Group 3, Er,Cr:YSGG

Figure 47 Representative photomicrographs of an Er,Cr:YSGG prepared Group 3 tooth (original magnification 30x, Specimen 21)

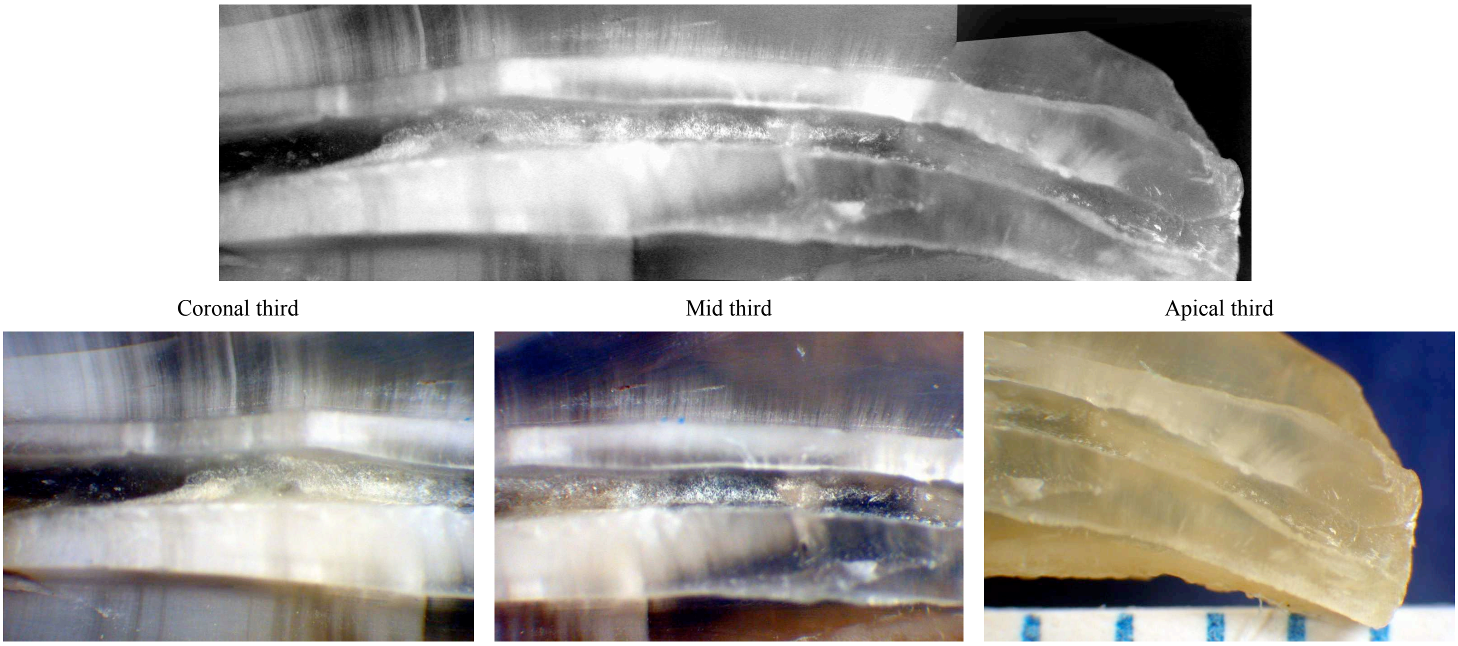
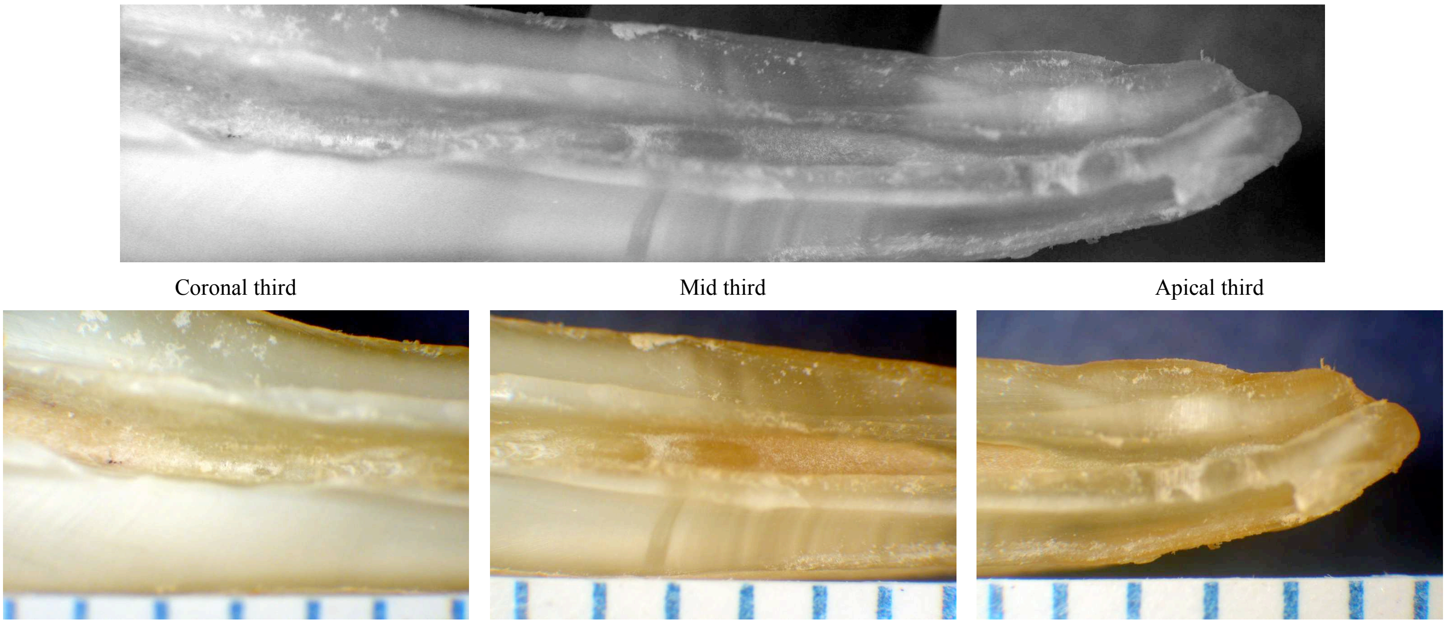


Figure 48 Representative photomicrographs of an Er,Cr:YSGG prepared Group 3 tooth (original magnification 30x, Specimen 126)



Group 4, Unprepared

Figure 49 Representative photomicrographs of an Unprepared Group 4 tooth (original magnification 30x, Specimen 30)

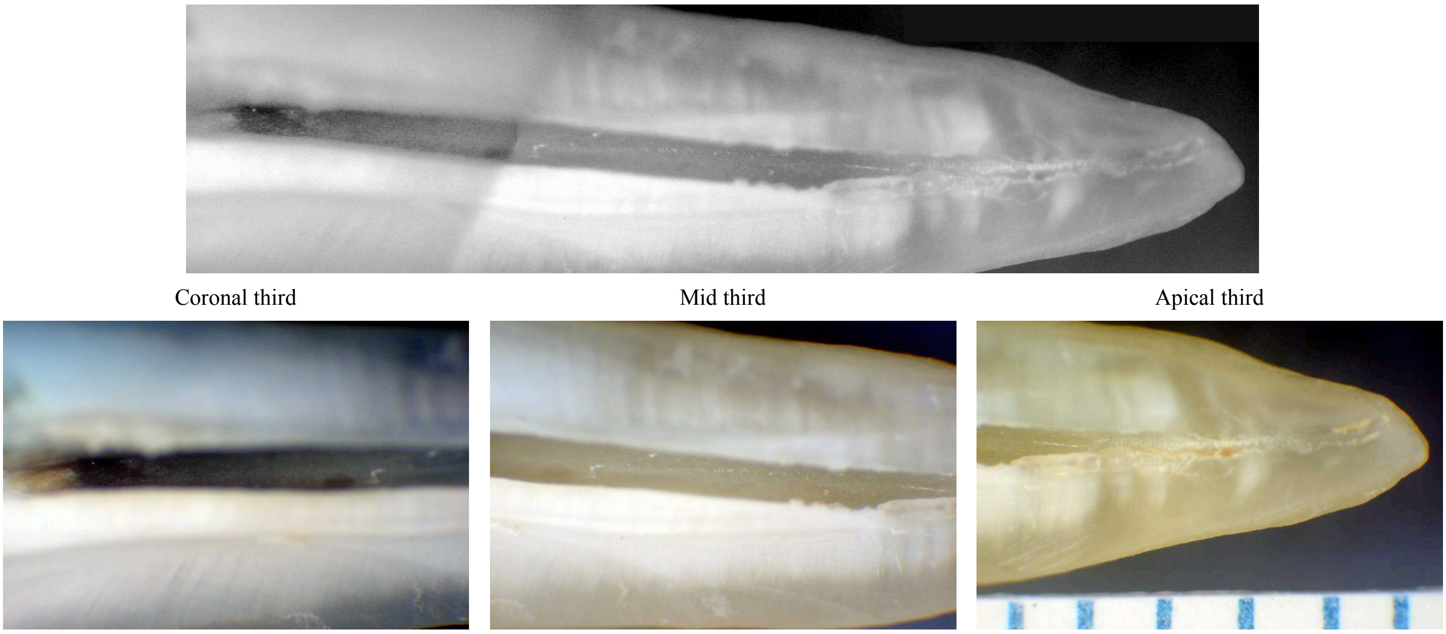
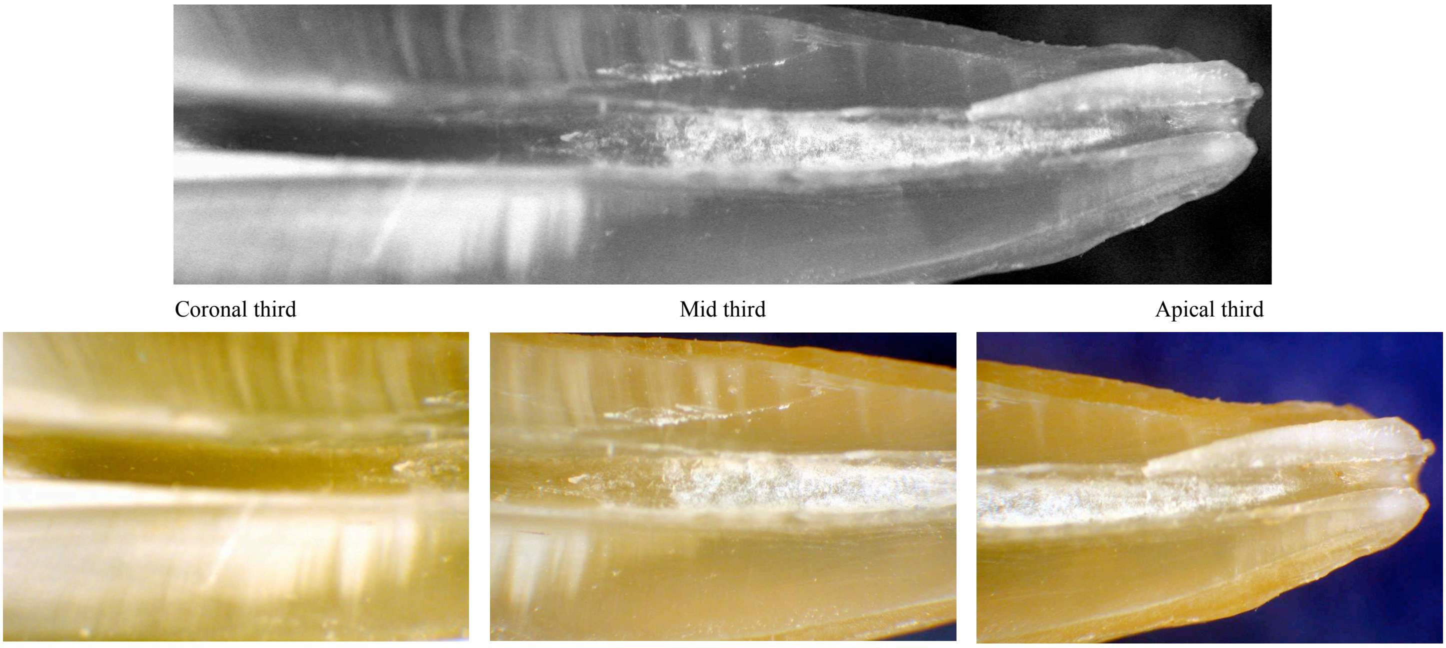


Figure 50 Representative photomicrographs of an Unprepared Group 4 tooth (original magnification 30x, Specimen 36)



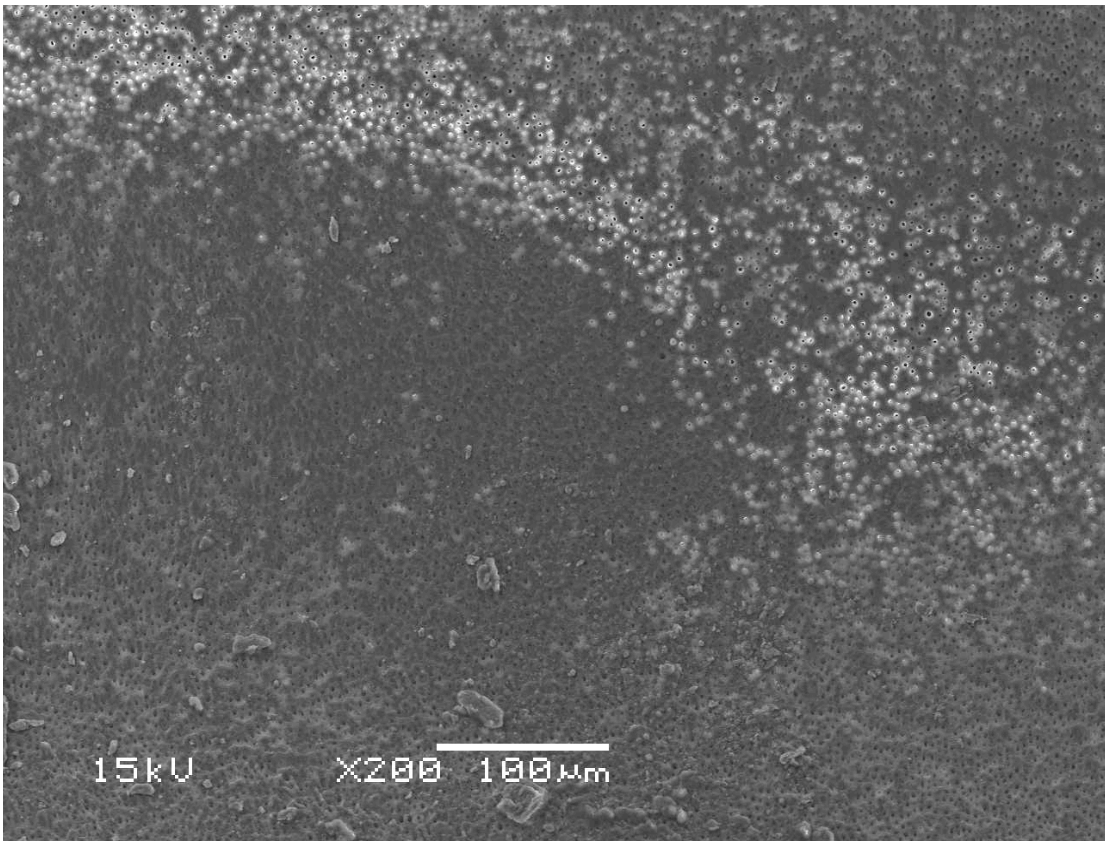
Appendix 7 Study 2 representative photomicrographs

Figure 51 Photomicrographs record the SEM images of a representative tooth from the NiTi Group (Specimen 85 a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

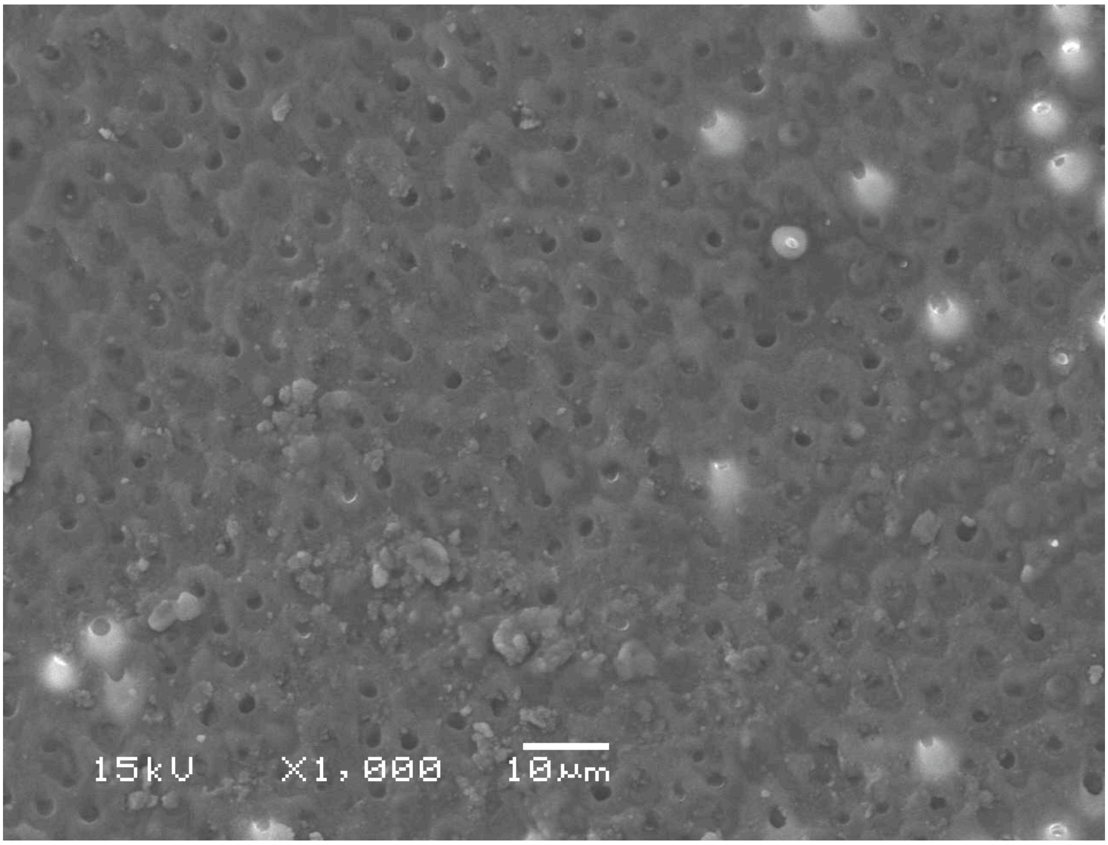
a)

Coronal third

b)

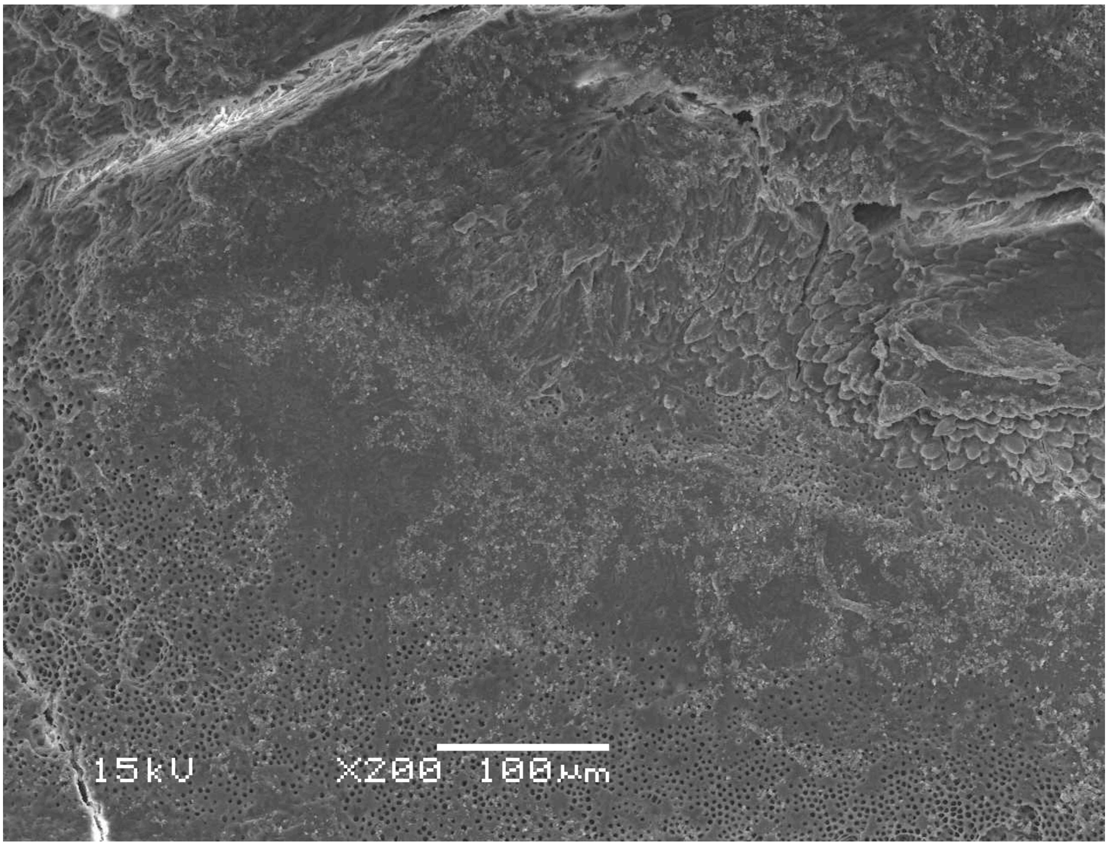


c)

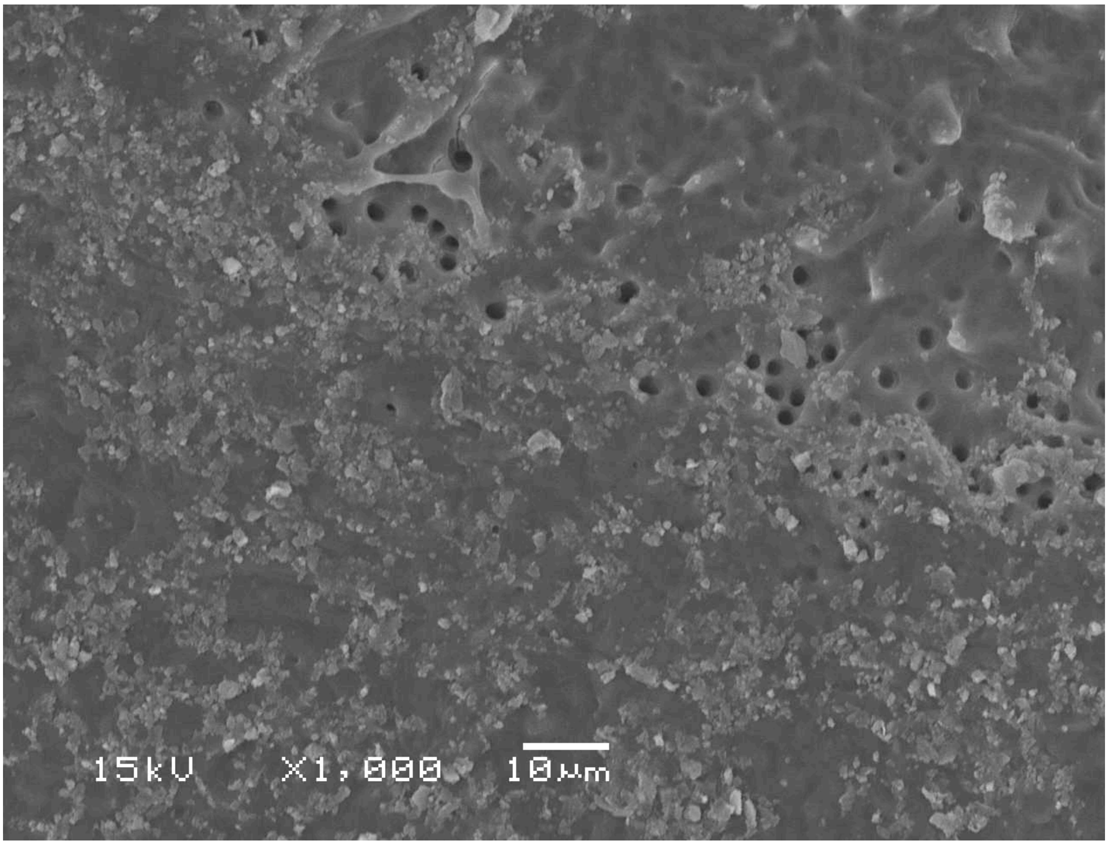


Mid third

d)

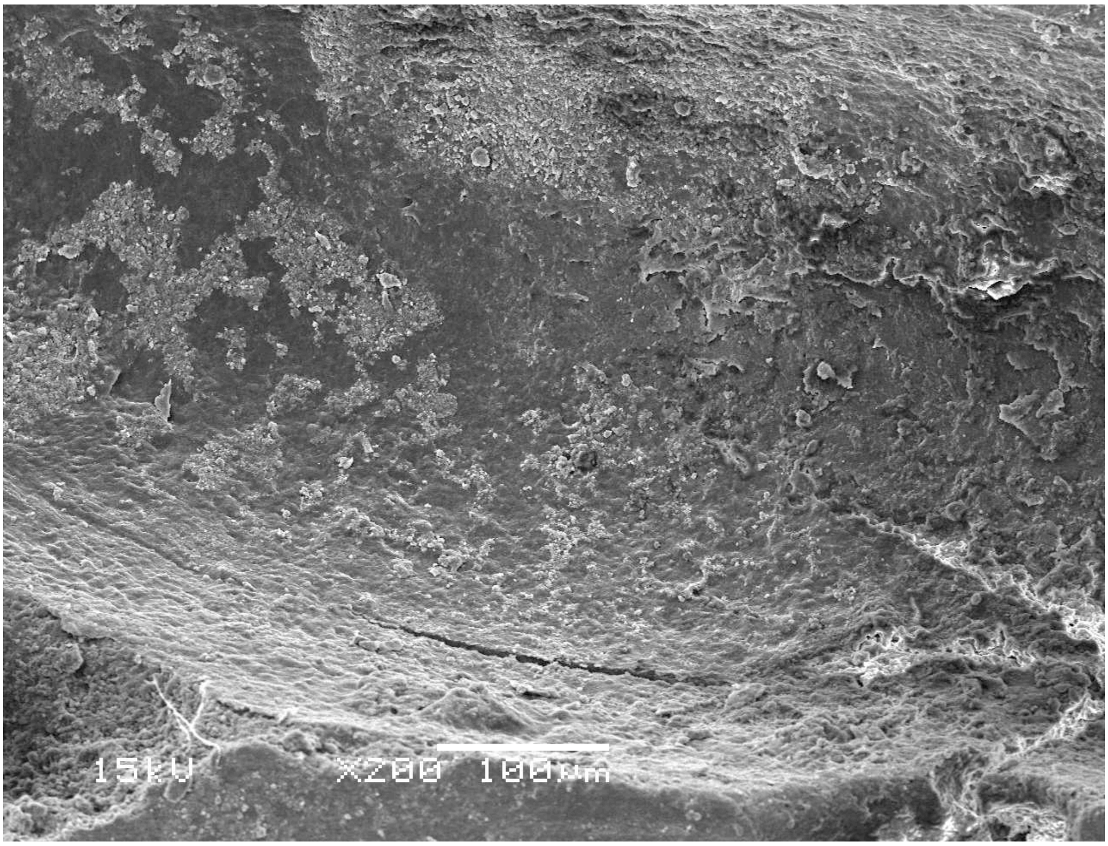


e)



Apical third

f)



g)

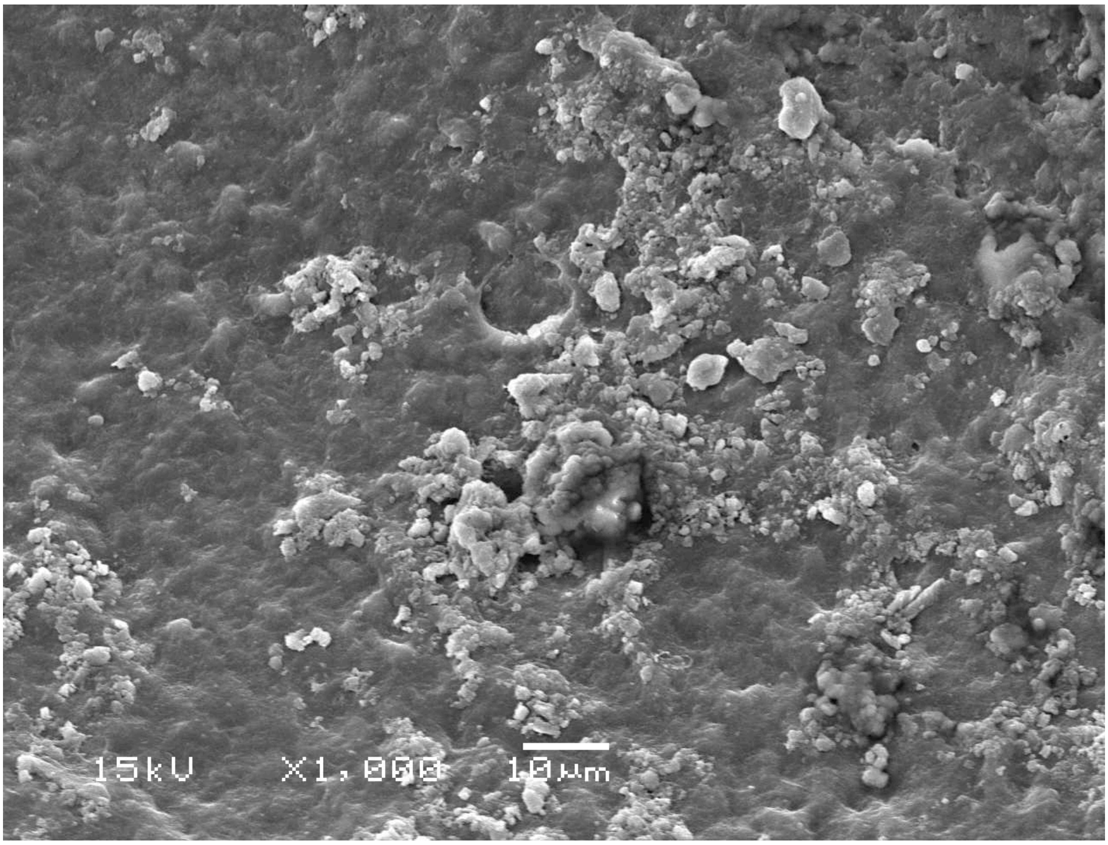
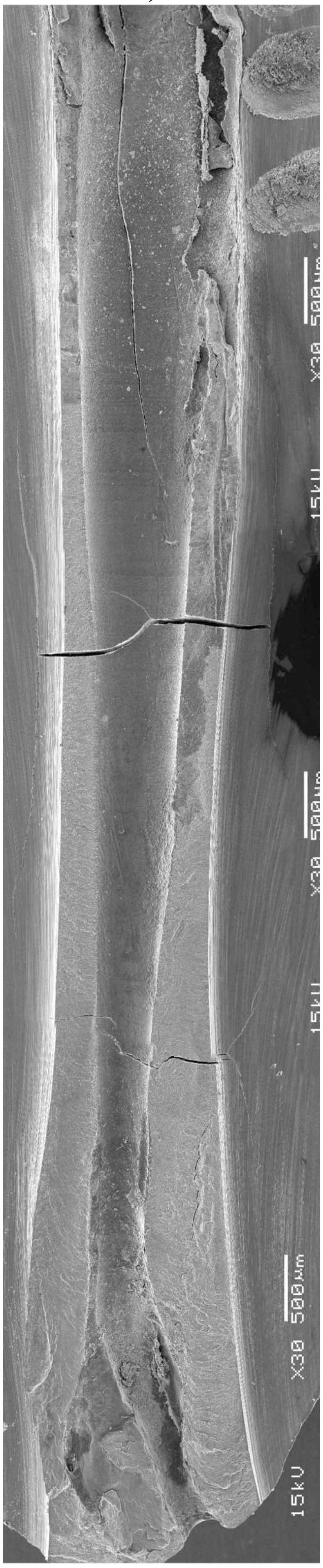


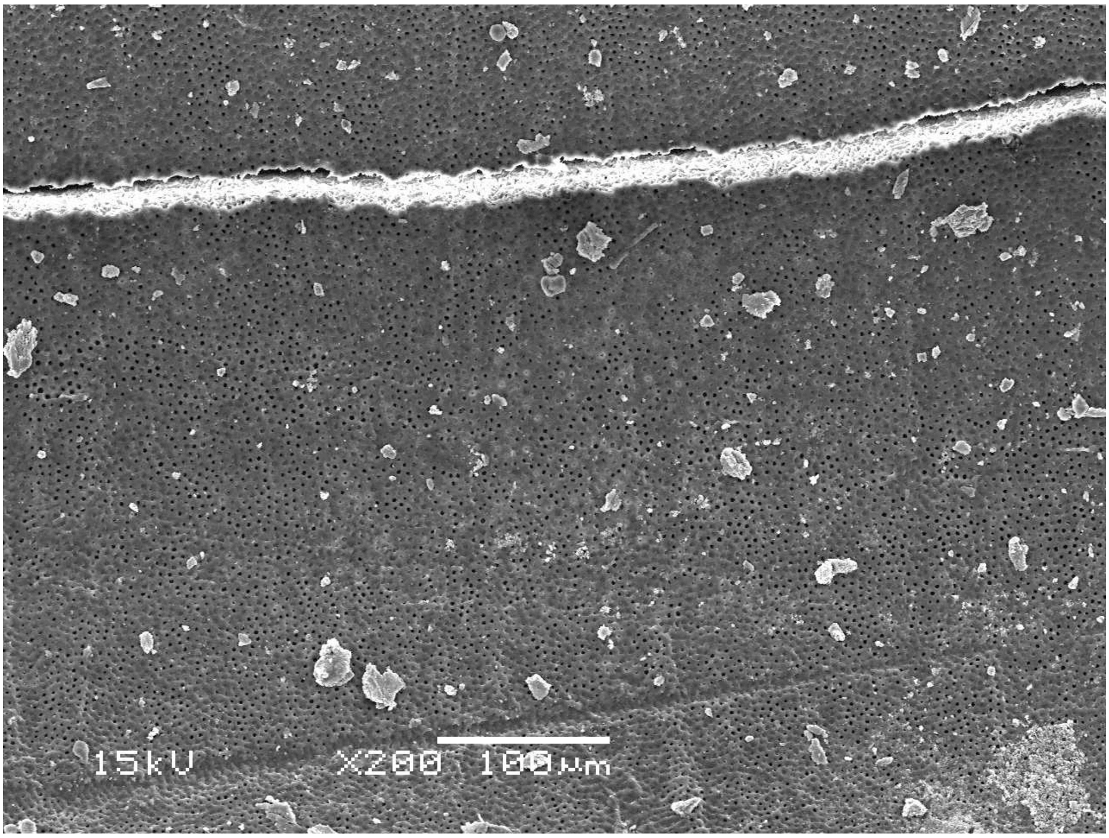
Figure 52 Photomicrographs record the SEM images of a representative tooth from the NiTi Group (Specimen 158); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

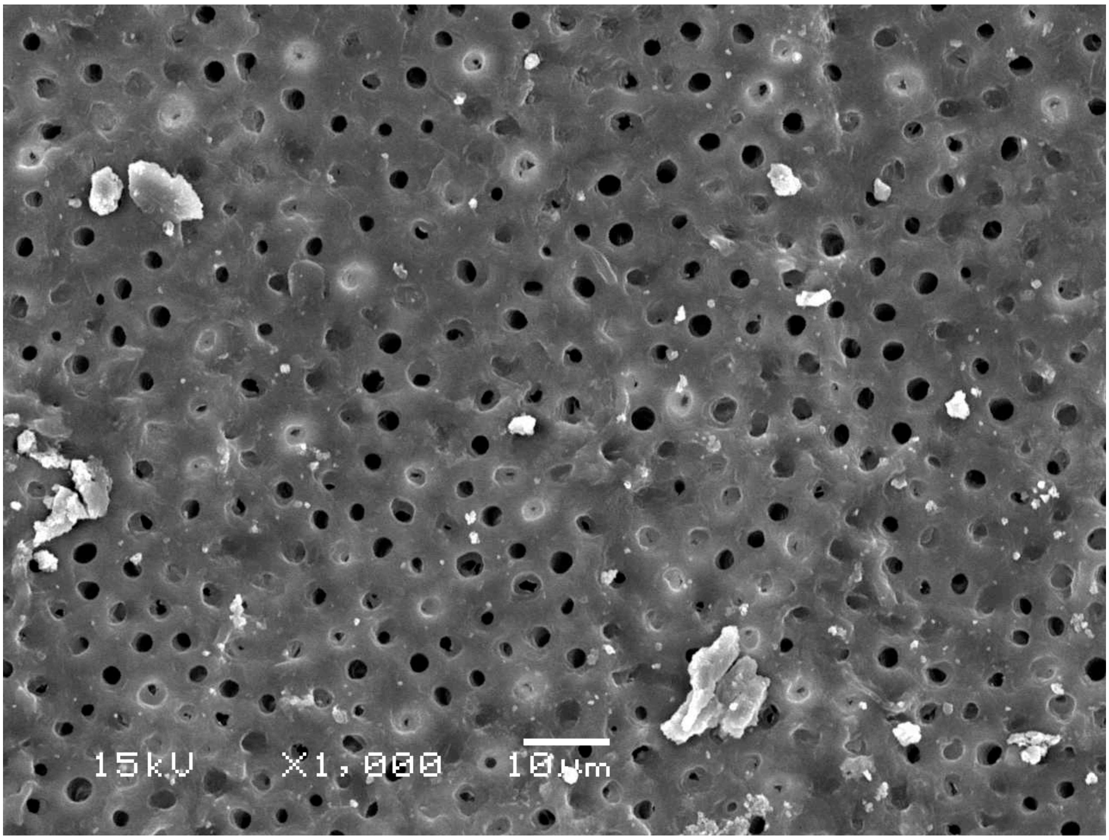


Coronal third

b)

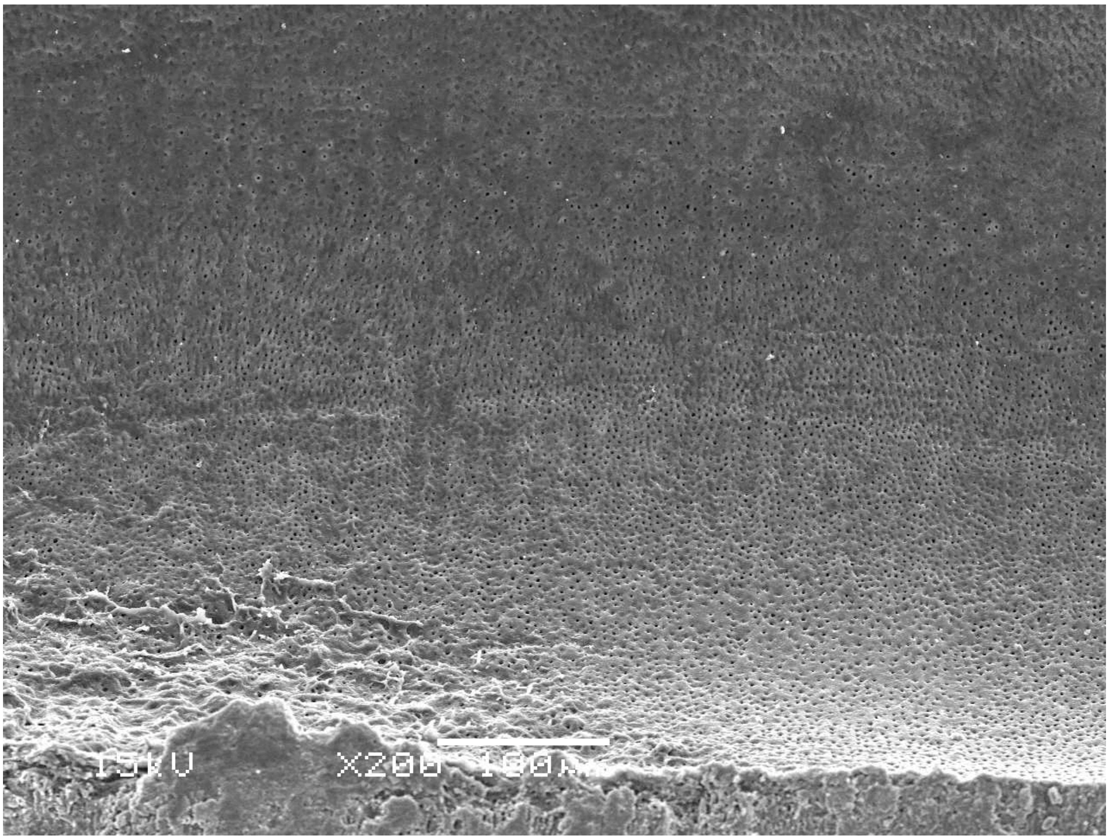


c)

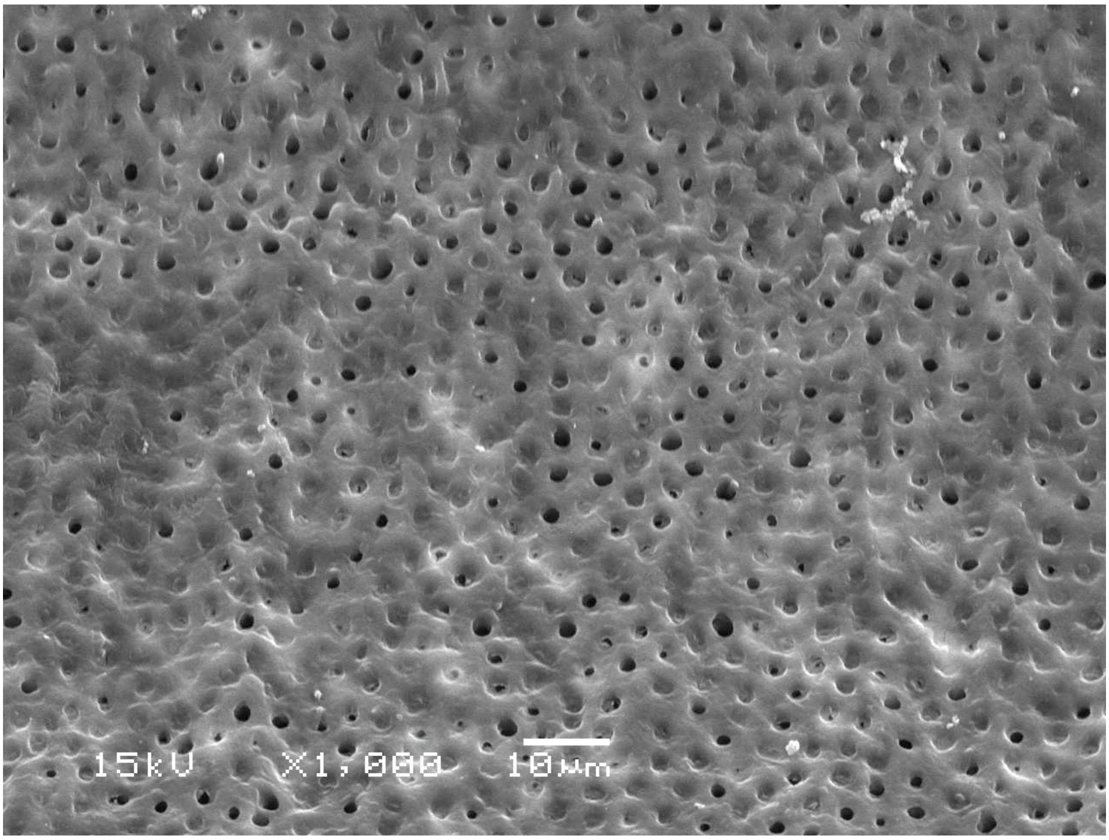


Mid third

d)

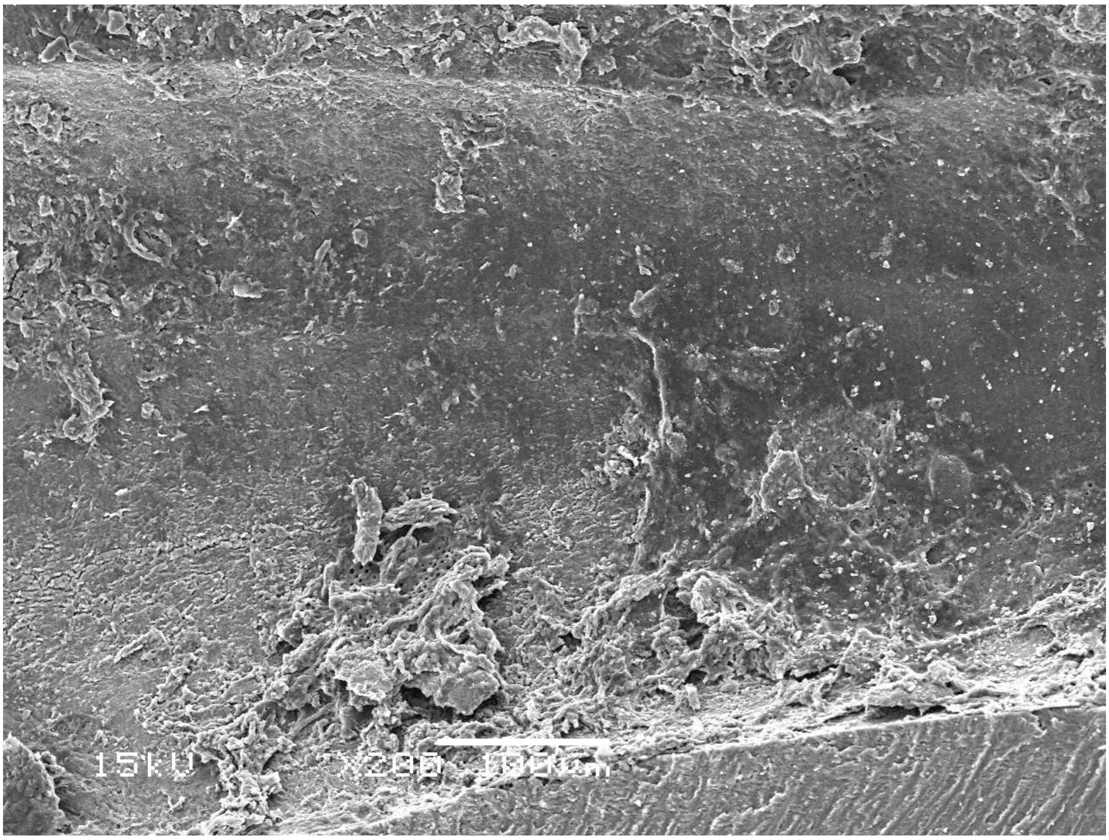


e)



Apical third

f)



g)

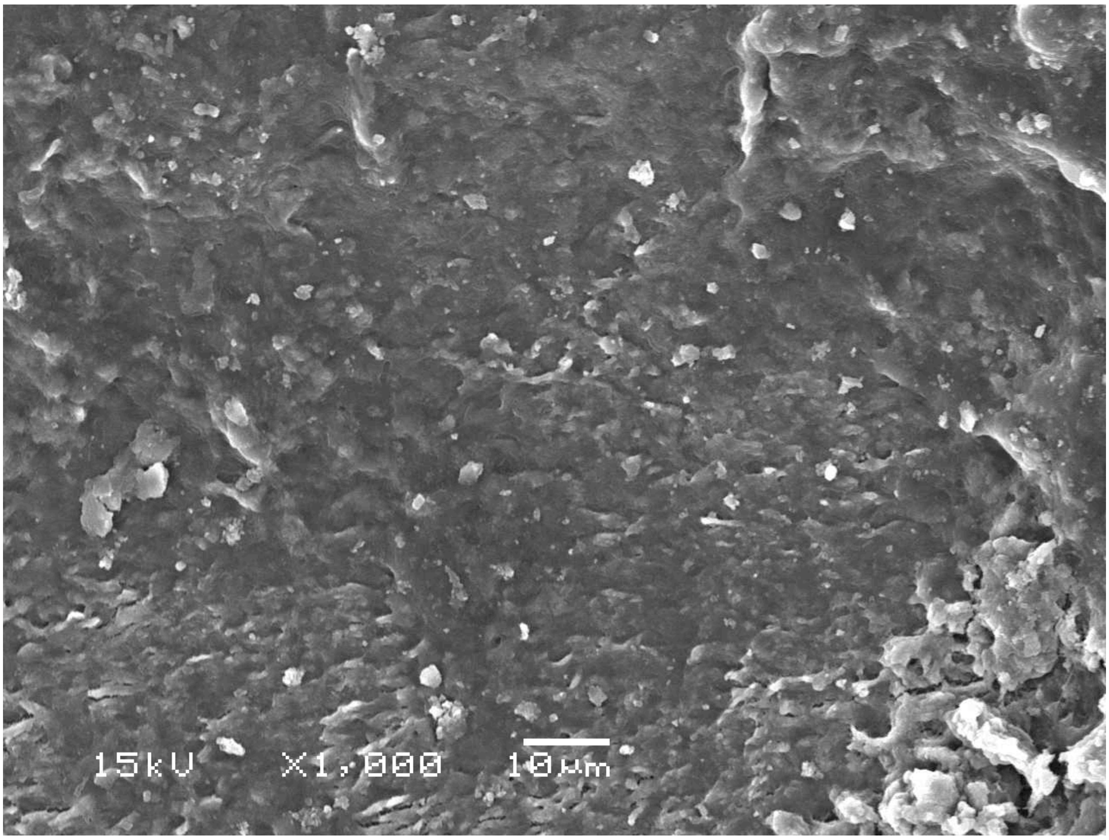
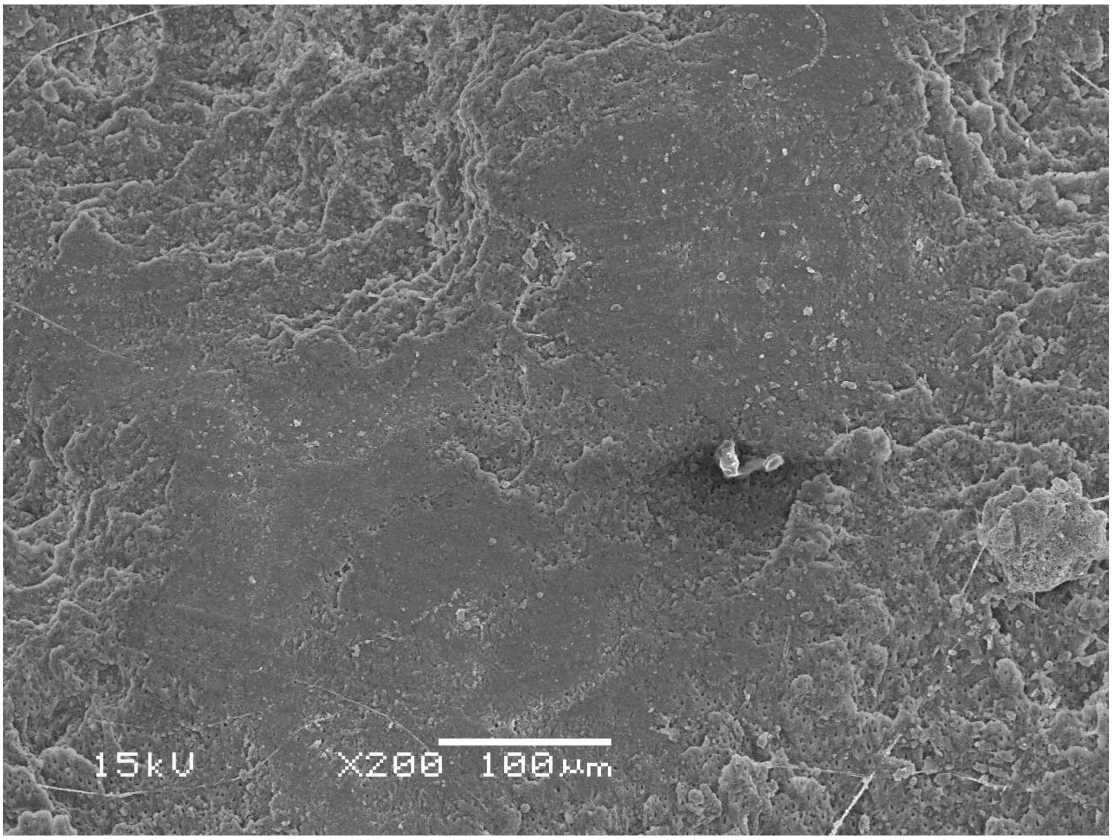


Figure 53 Photomicrographs record the SEM images of a representative tooth from the Er:YAG Group (Specimen 59); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

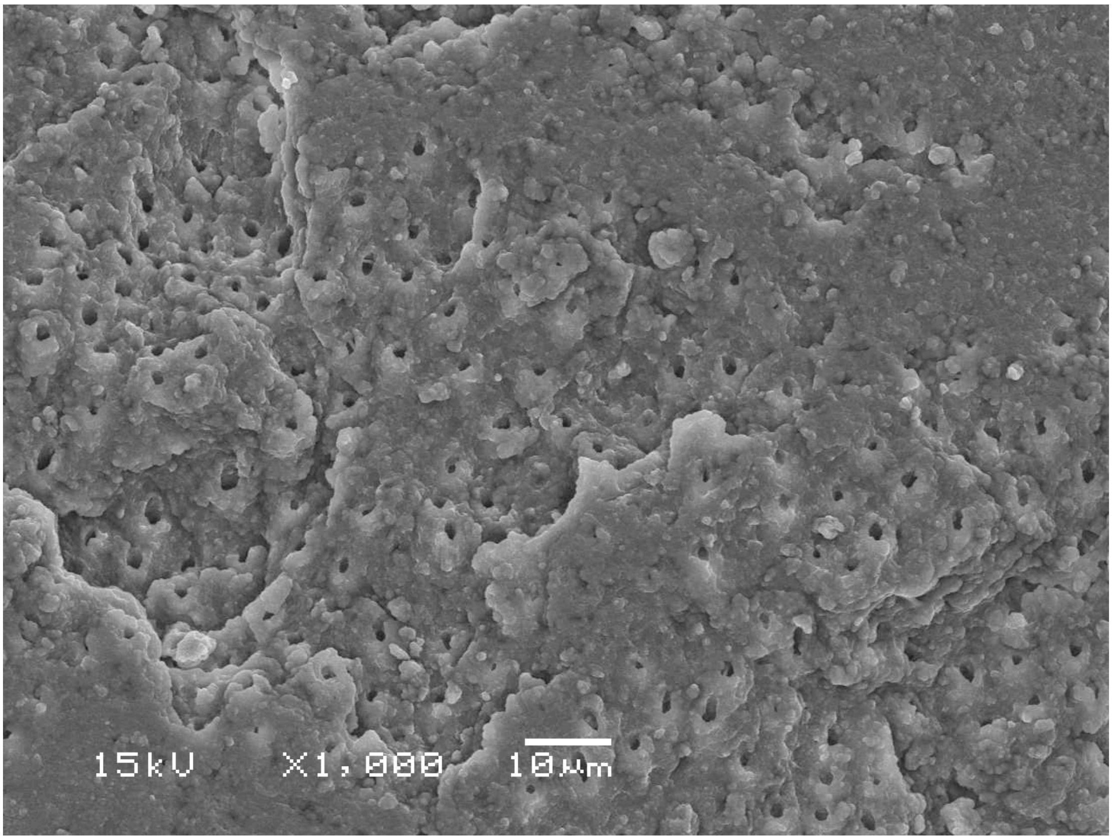
a)

Coronal third

b)

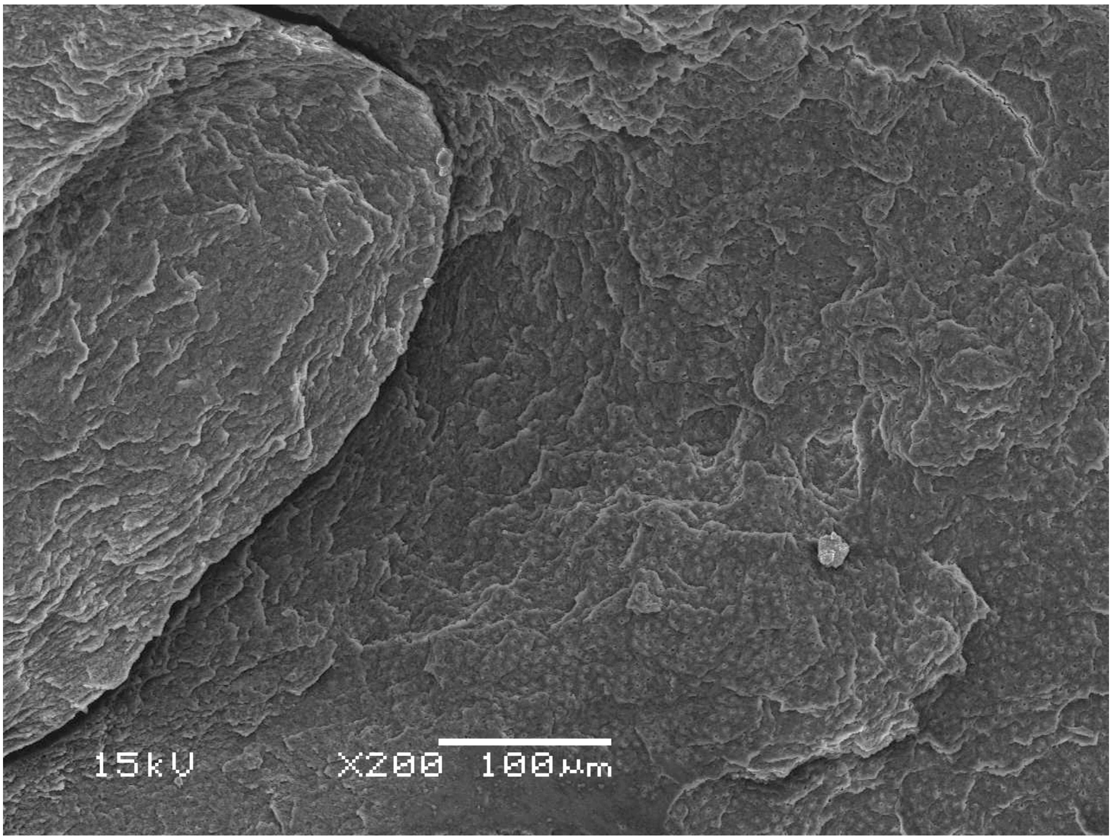


c)

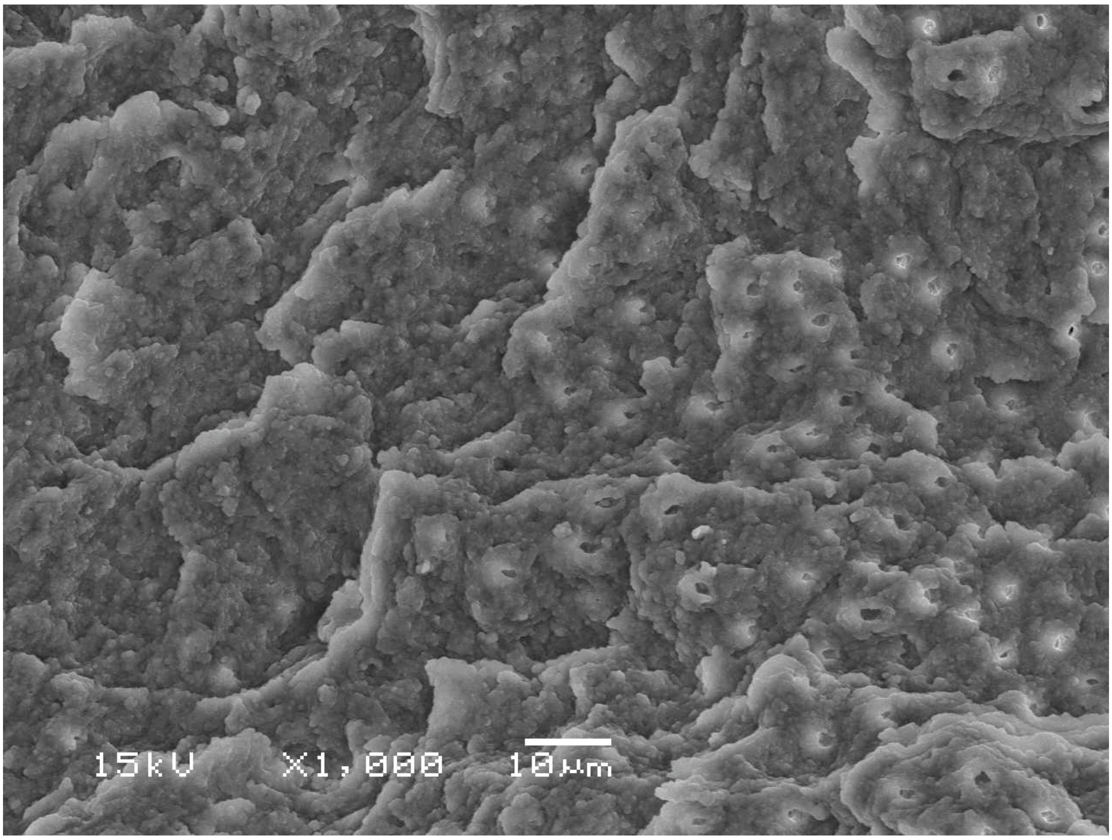


Mid third

d)

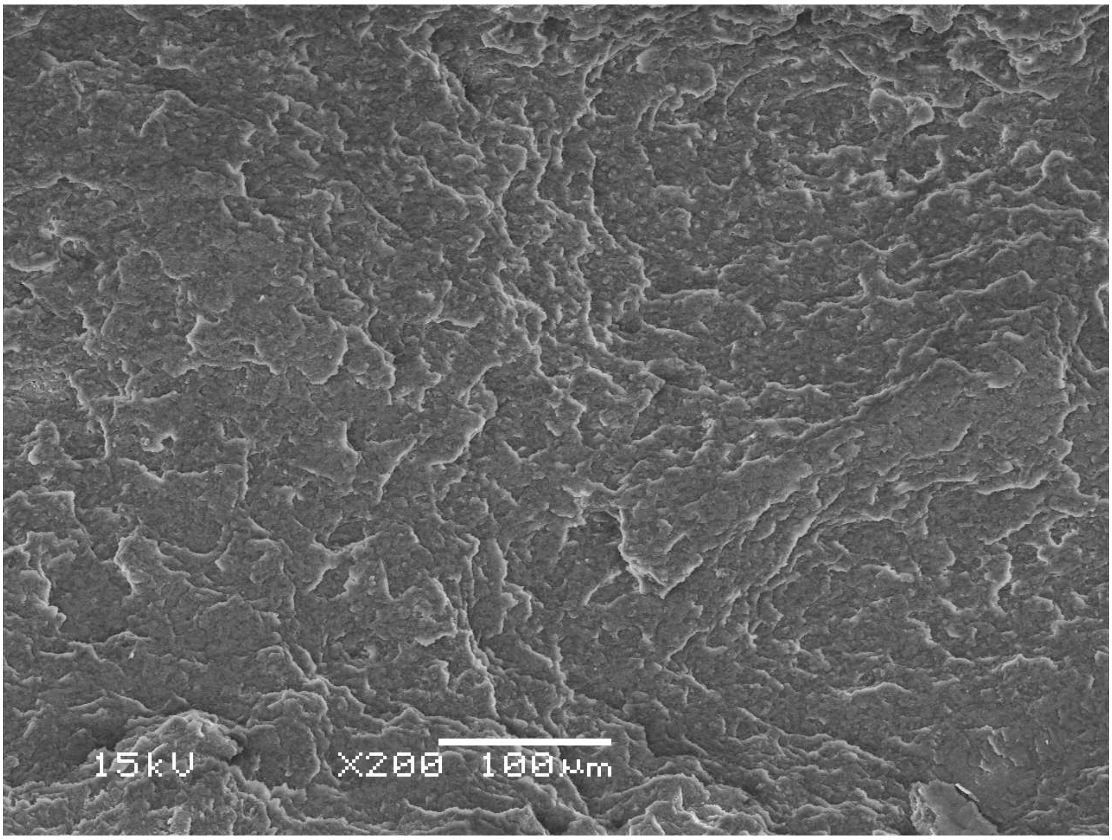


e)



Apical third

f)



g)

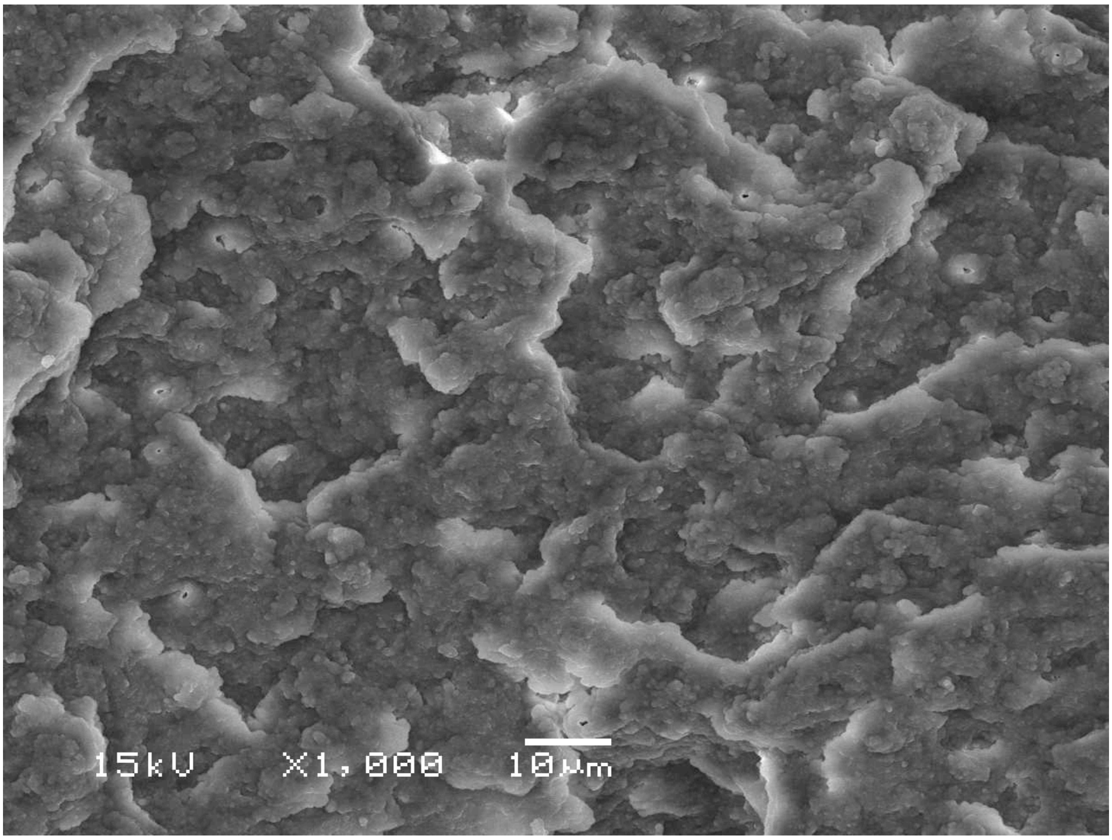
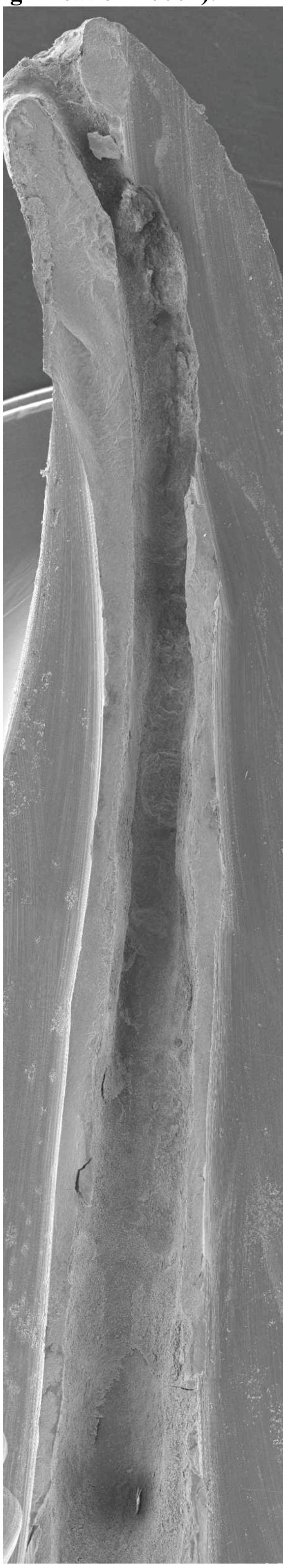


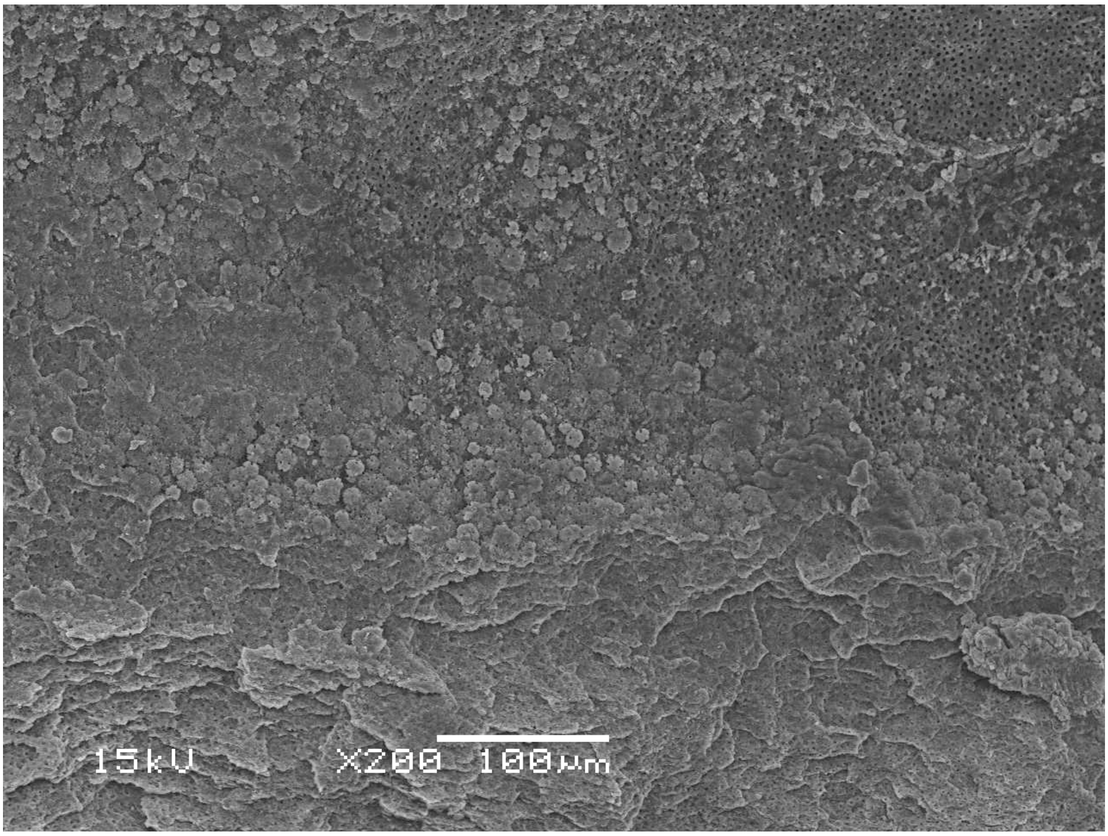
Figure 54 Photomicrographs record the SEM images of a representative tooth from the Er:YAG Group (Specimen 132); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

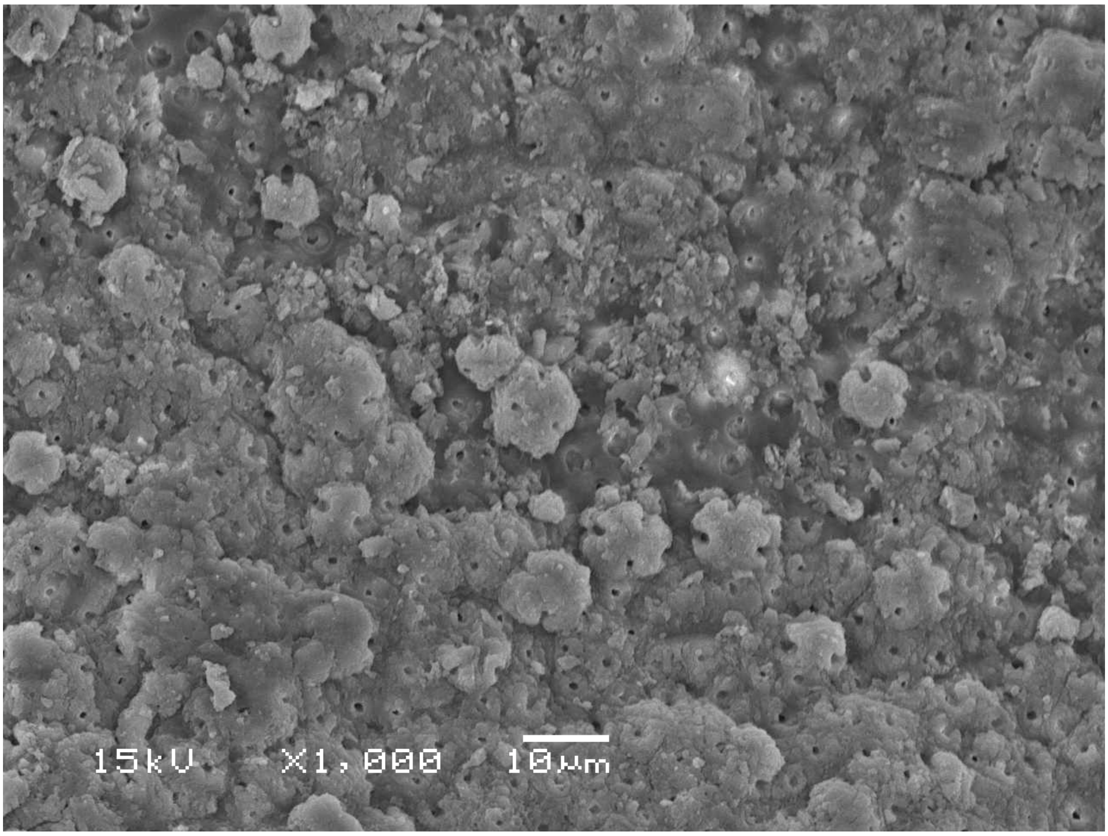


Coronal third

b)

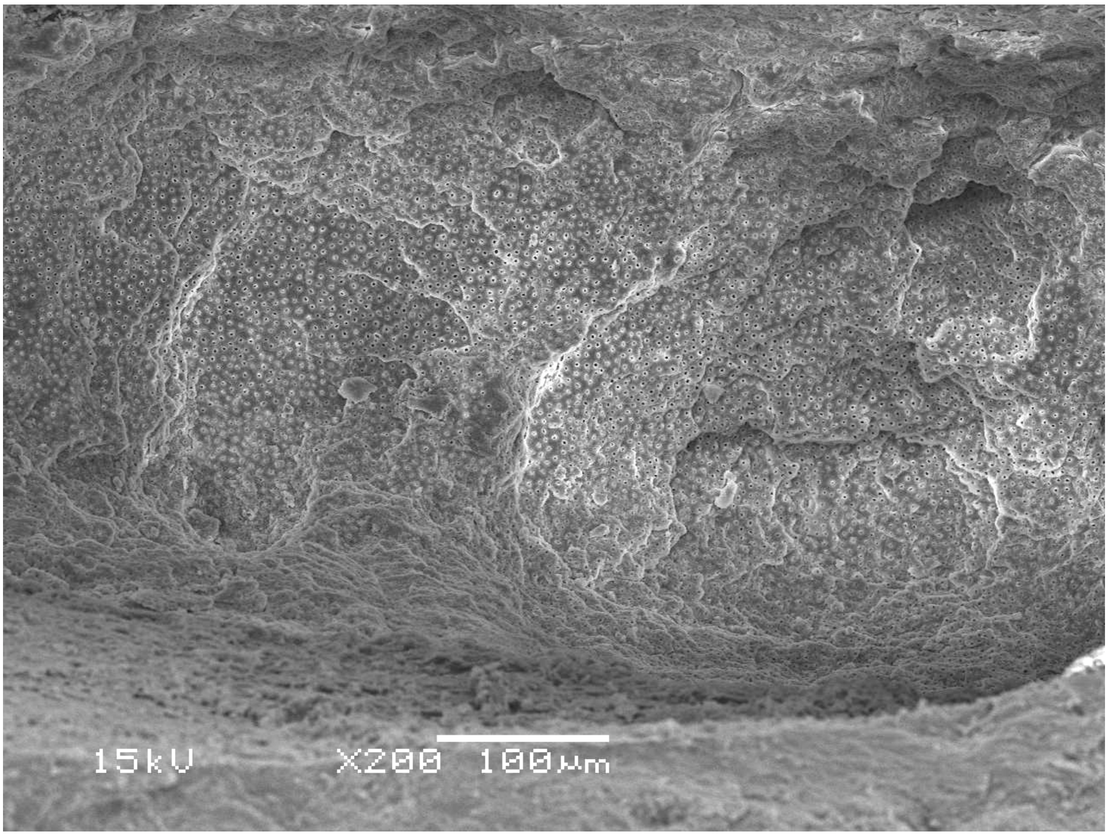


c)

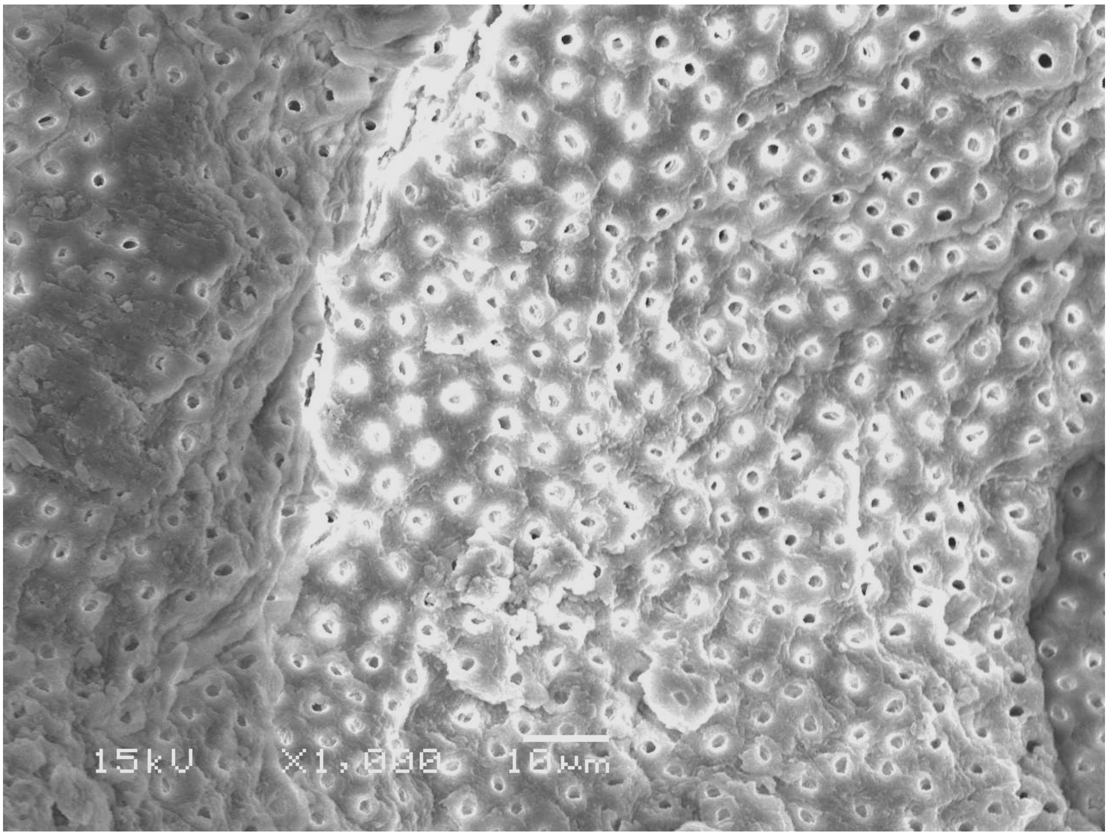


Mid third

d)

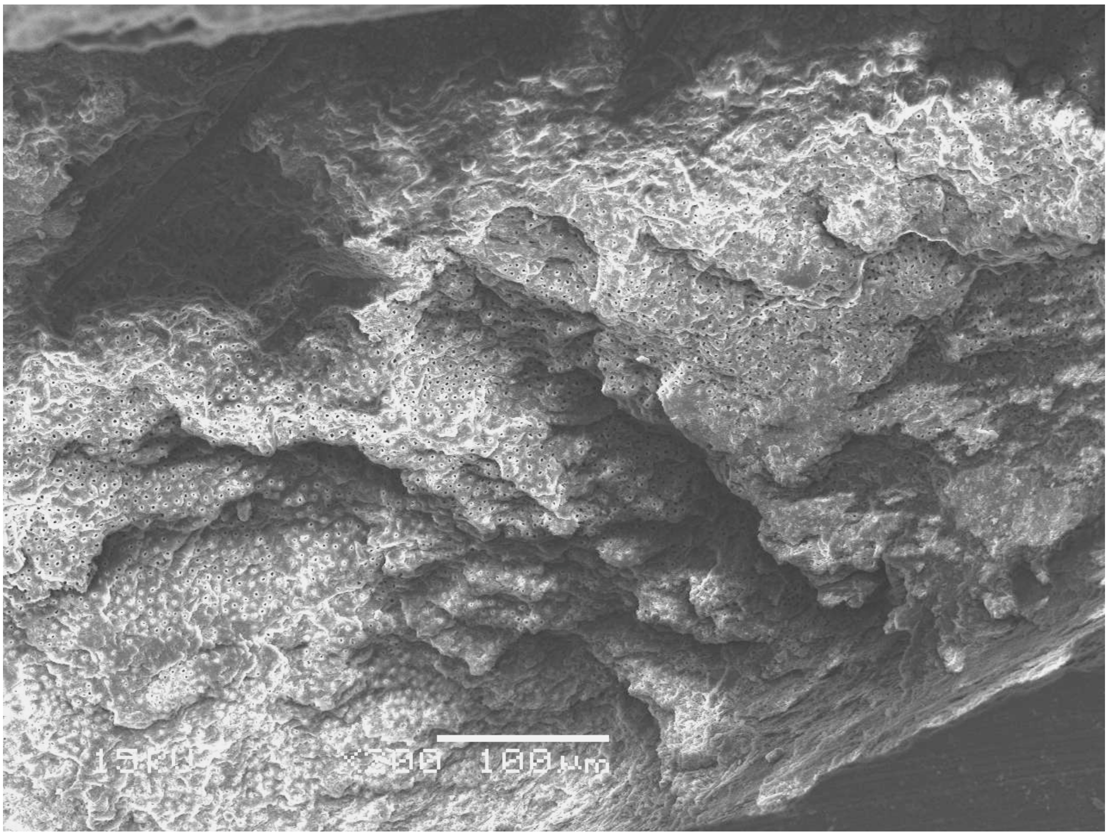


e)



Apical third

f)



g)

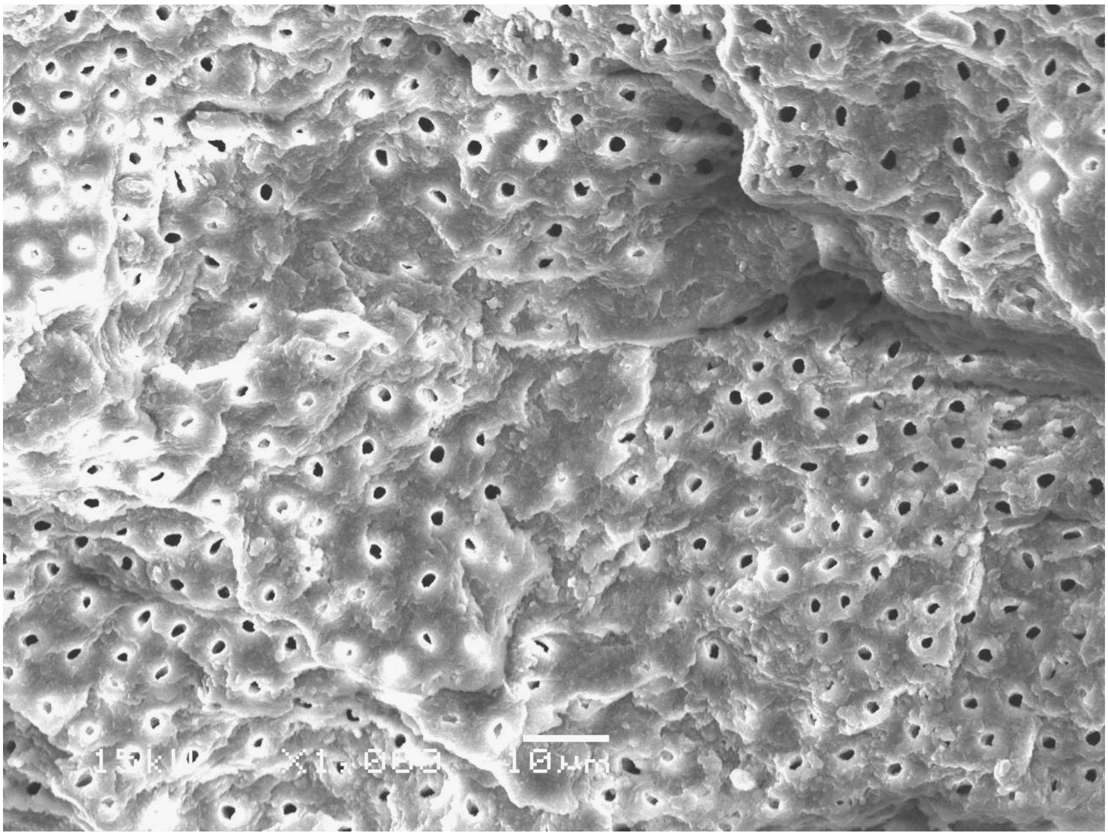
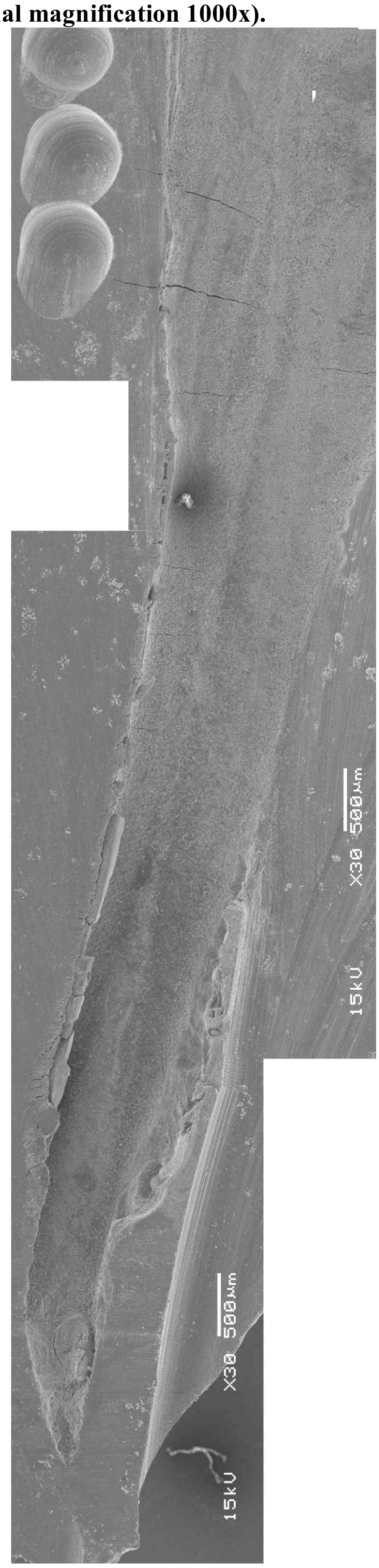


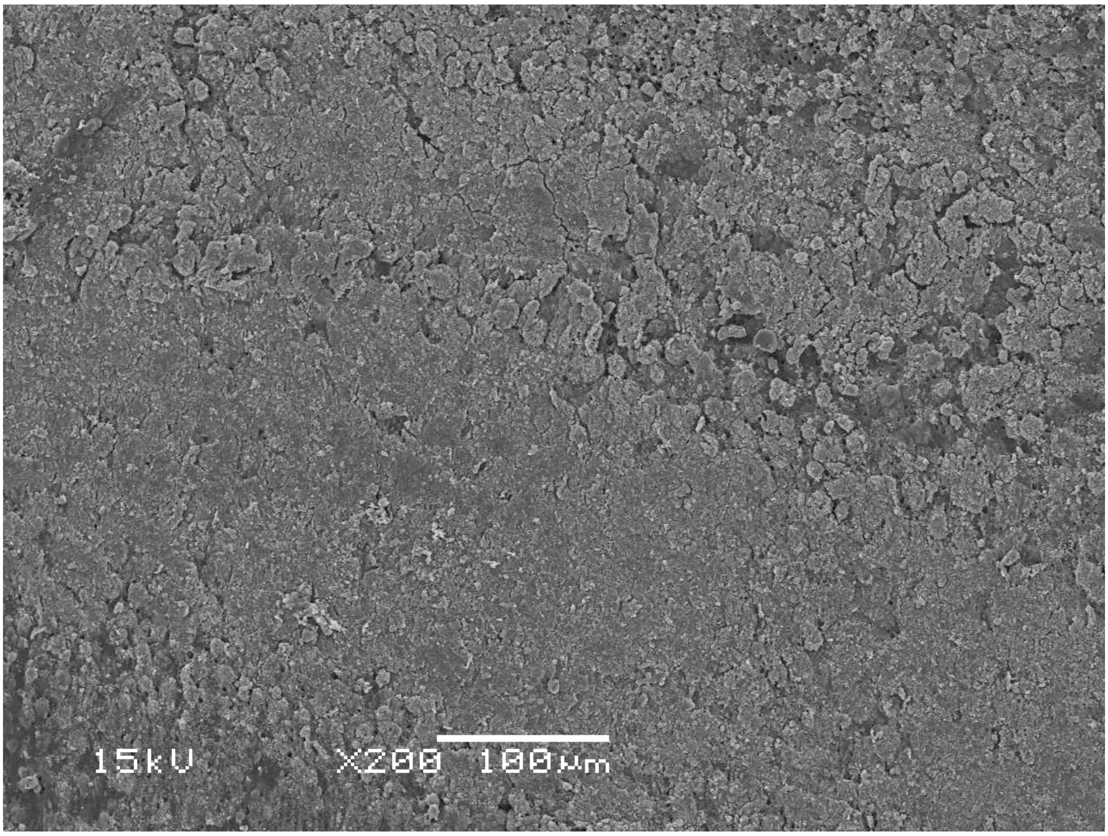
Figure 55 Photomicrographs record the SEM images of a representative tooth from the Er,Cr:YSGG Group (Specimen 29); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

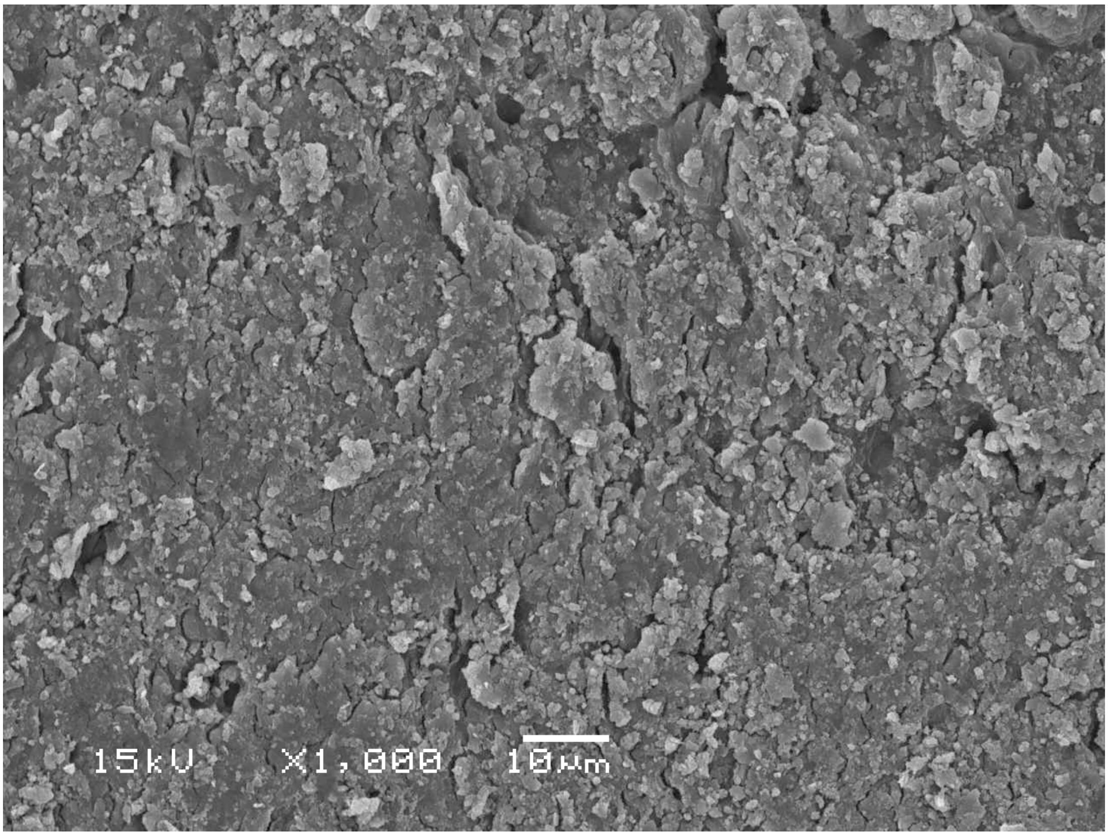


Coronal third

b)

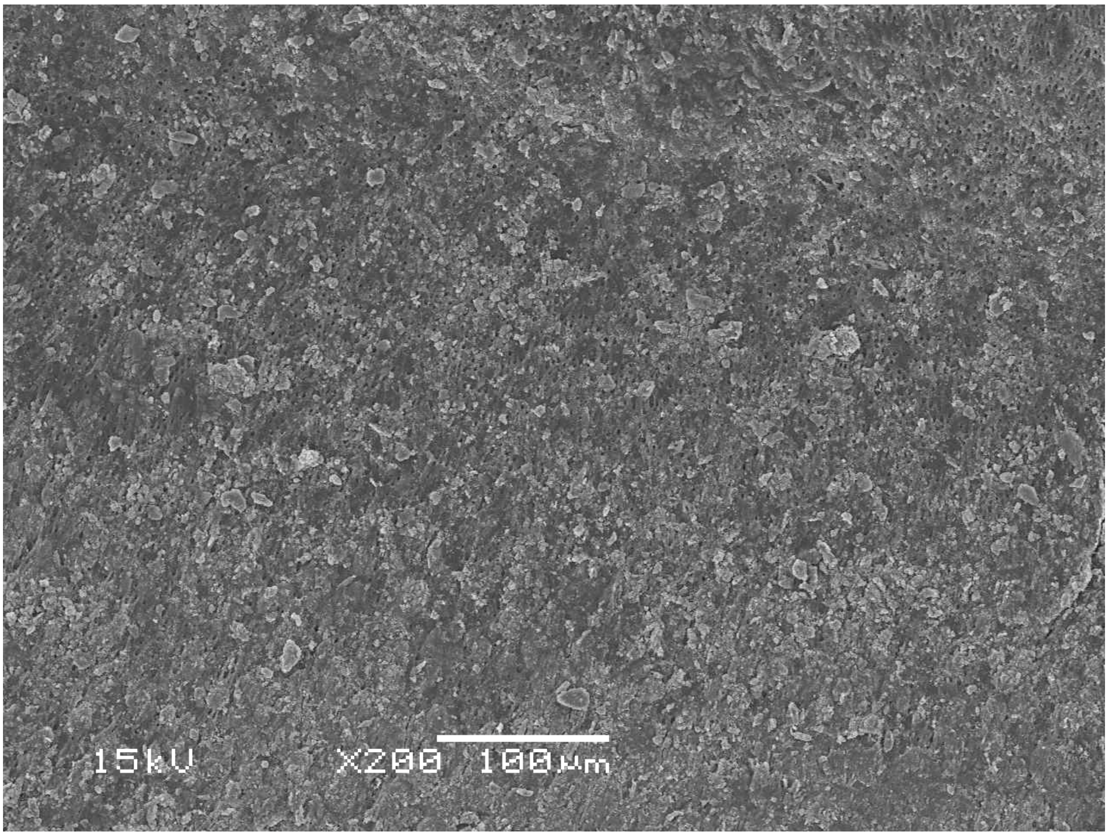


c)

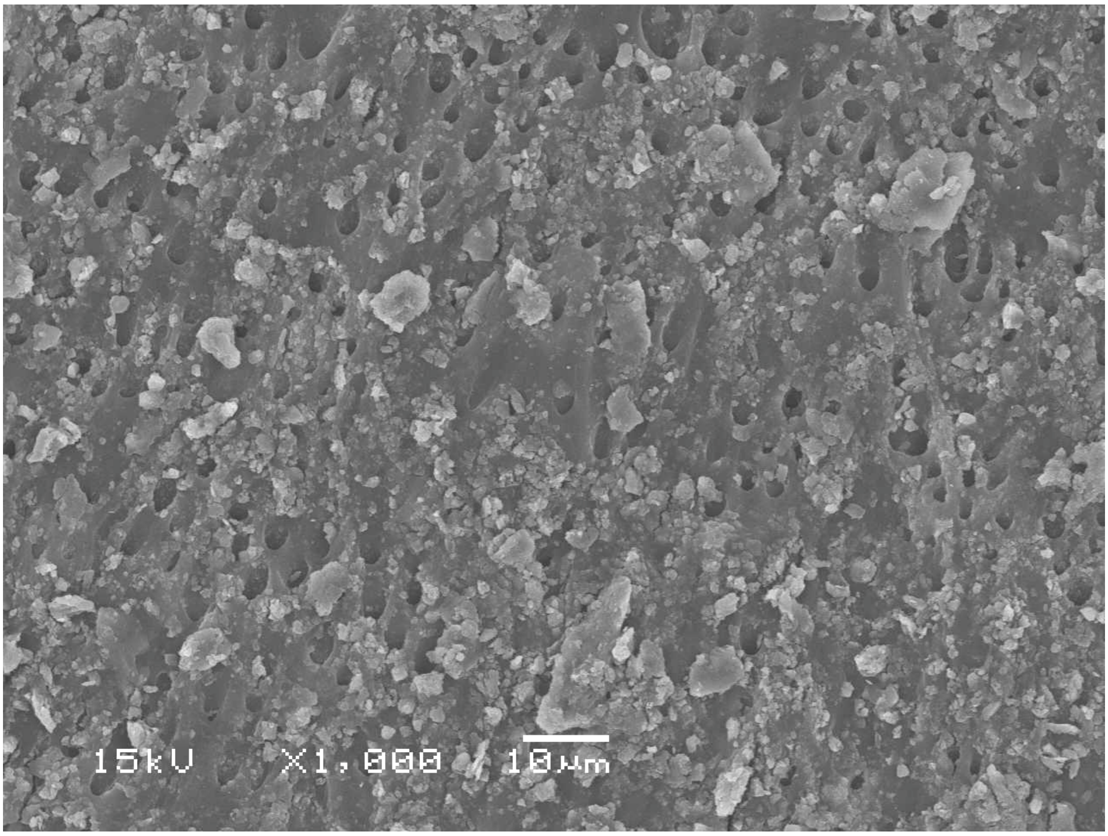


Mid third

d)

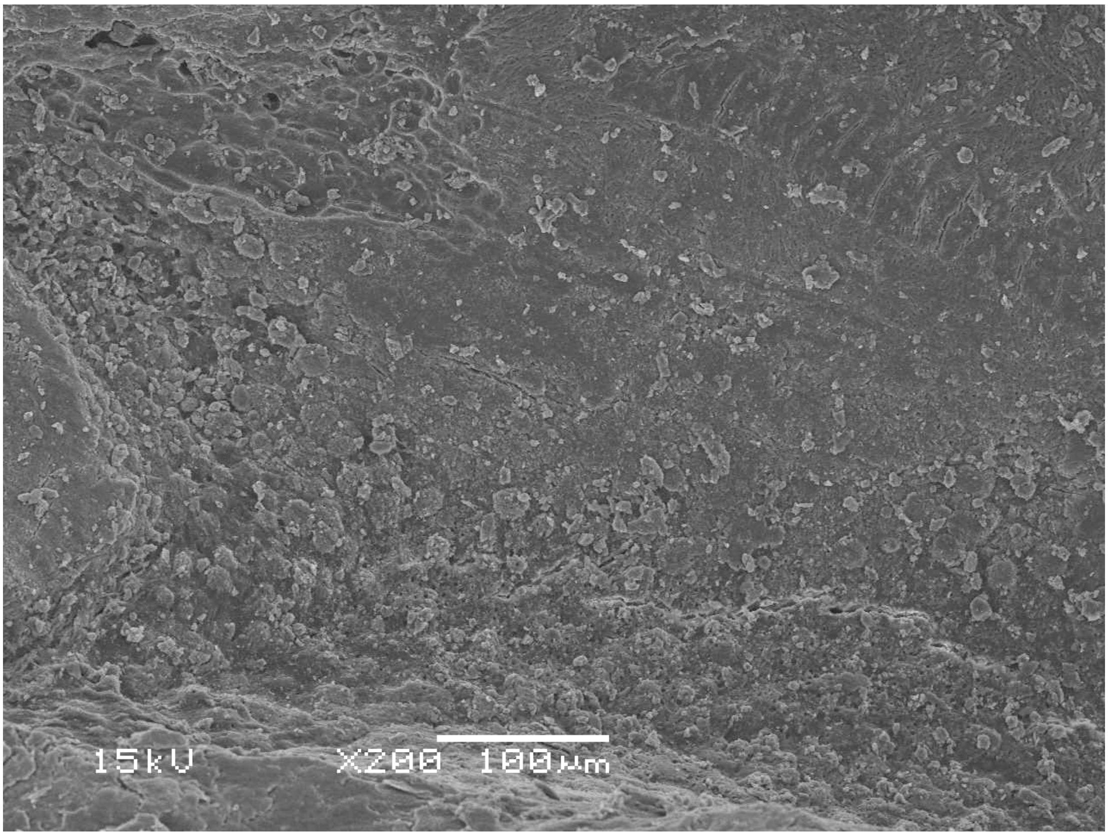


e)



Apical third

f)



g)

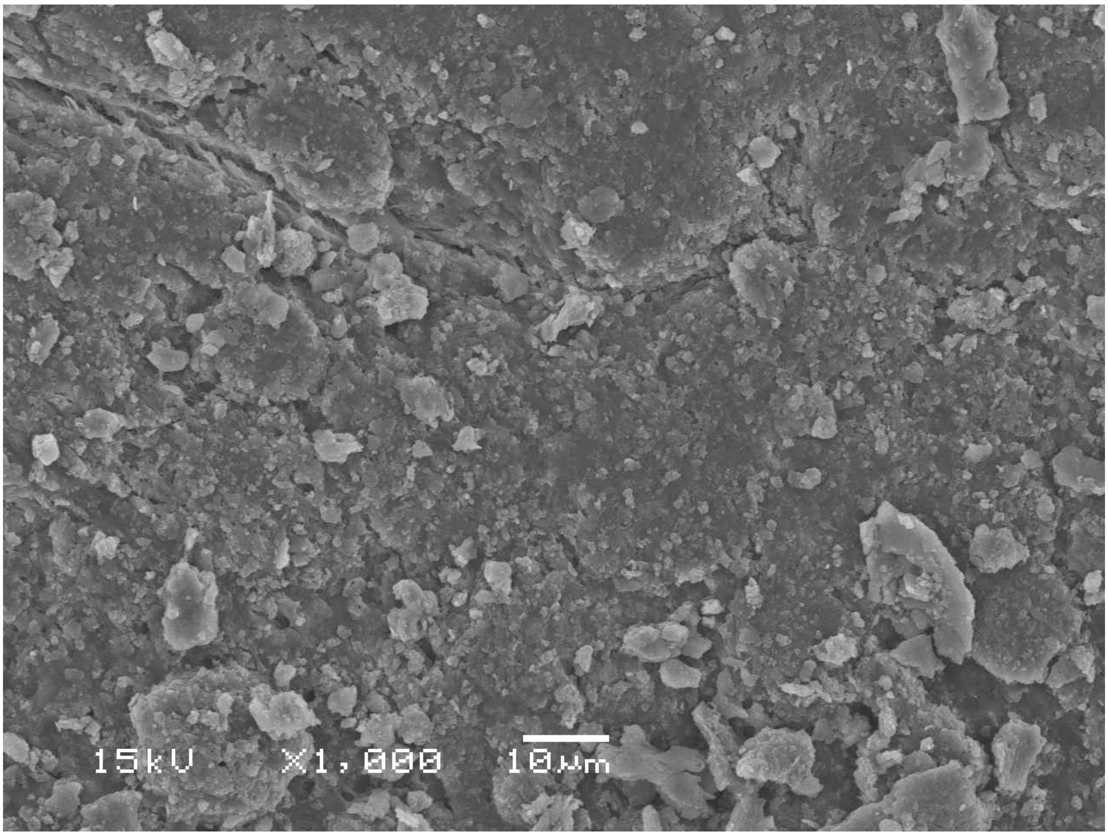
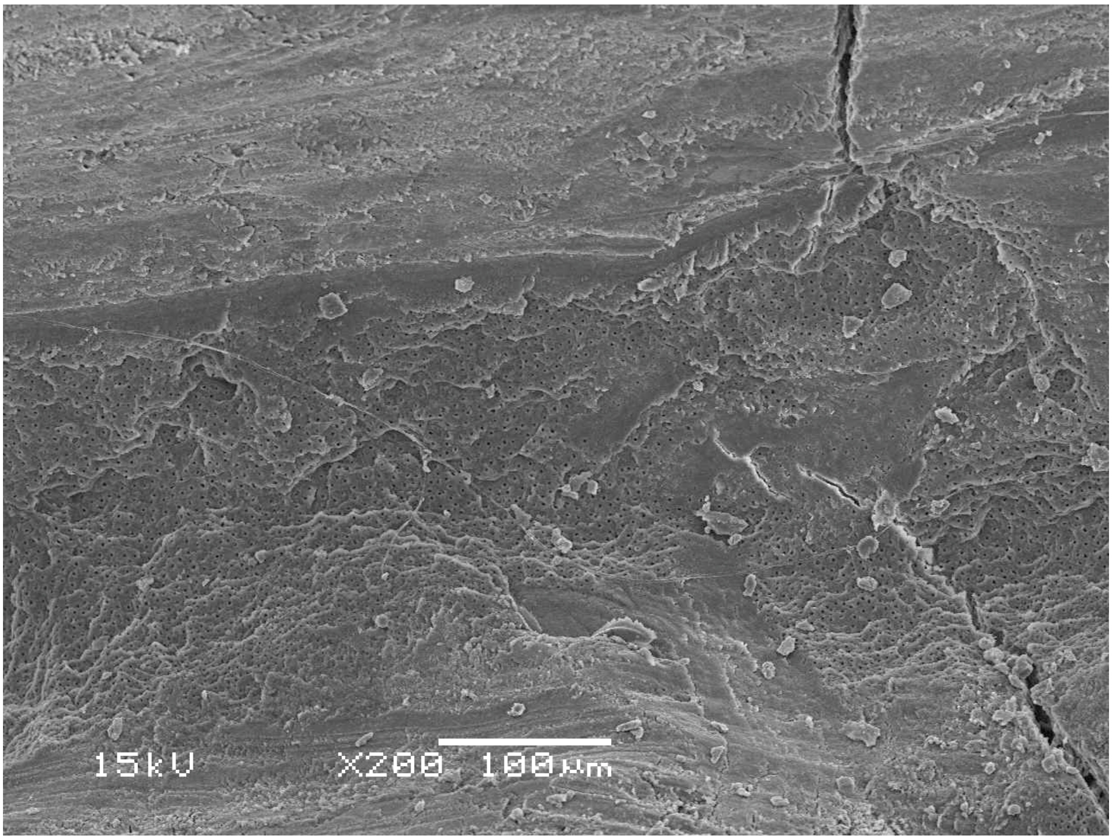


Figure 56 Photomicrographs record the SEM images of a representative tooth from the Er,Cr:YSGG Group (Specimen 92); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

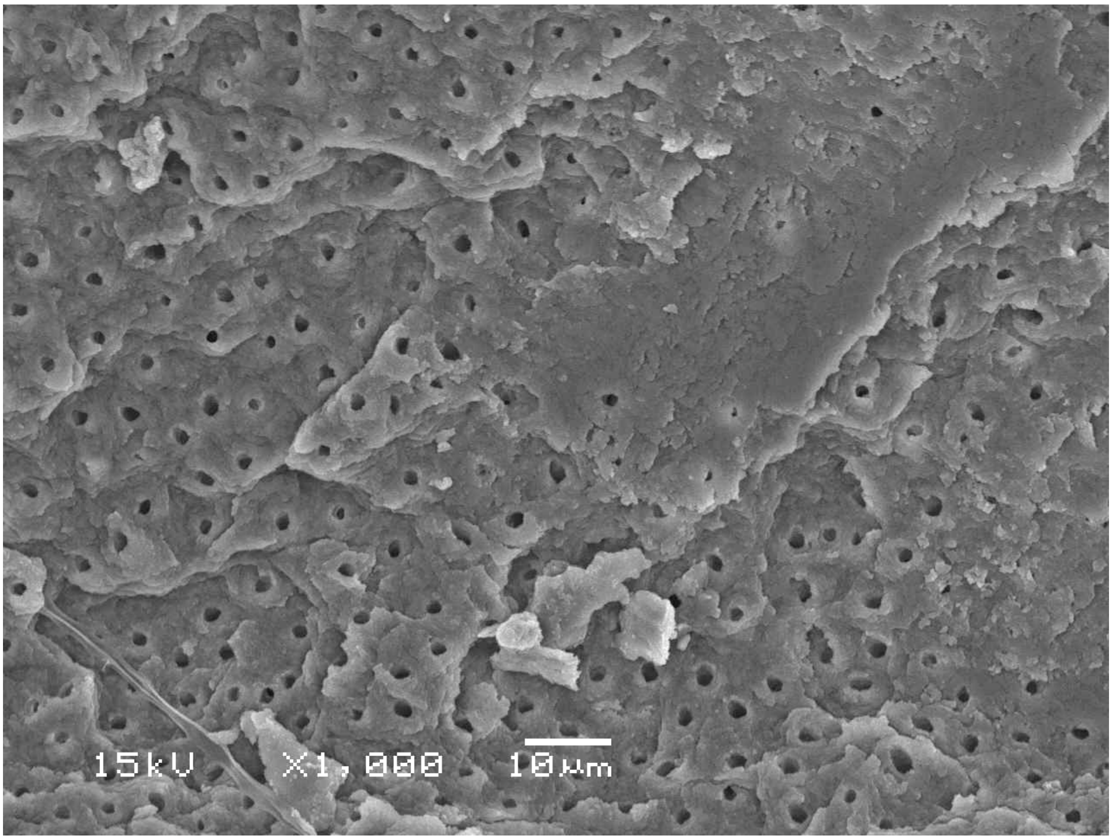
a)

Coronal third

b)

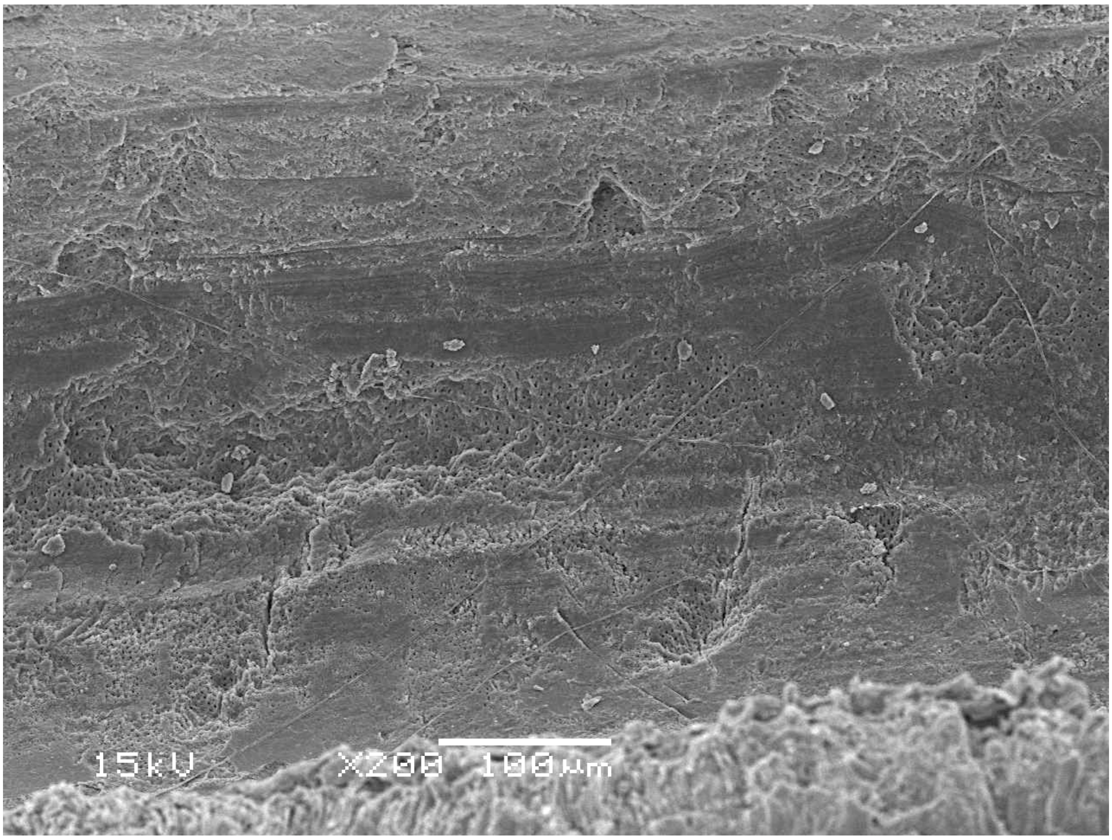


c)

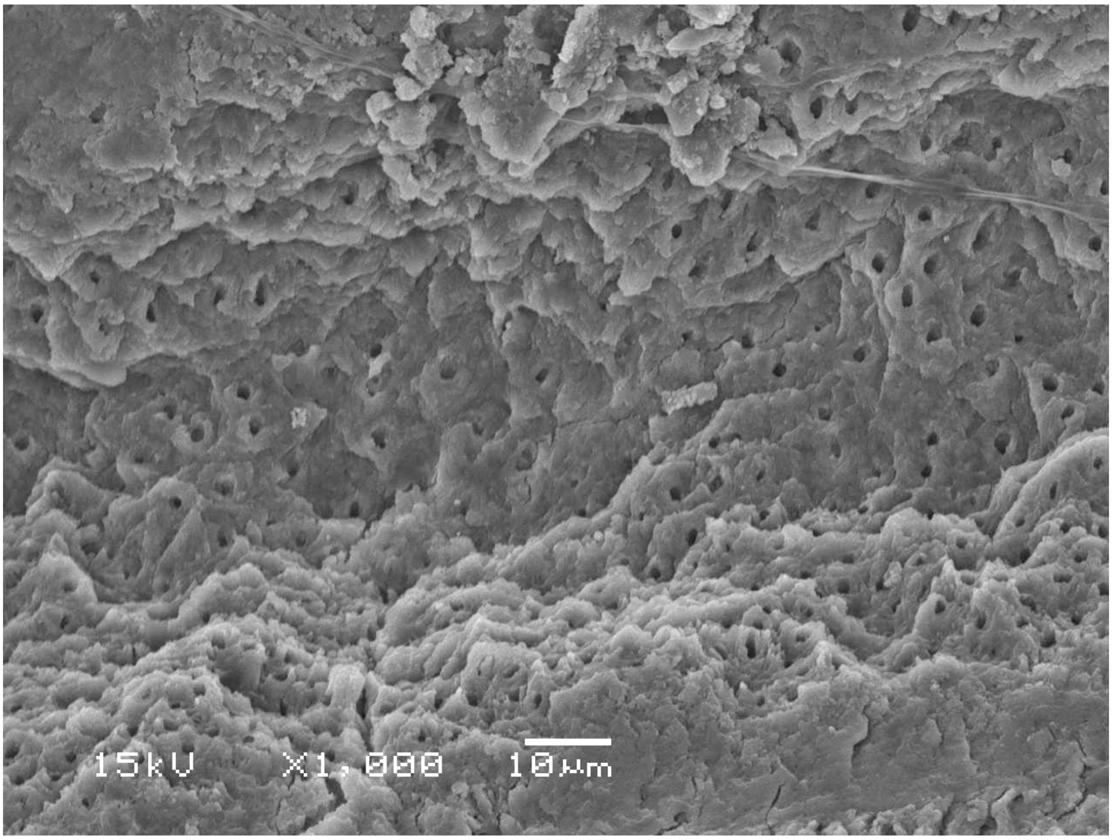


Mid third

d)

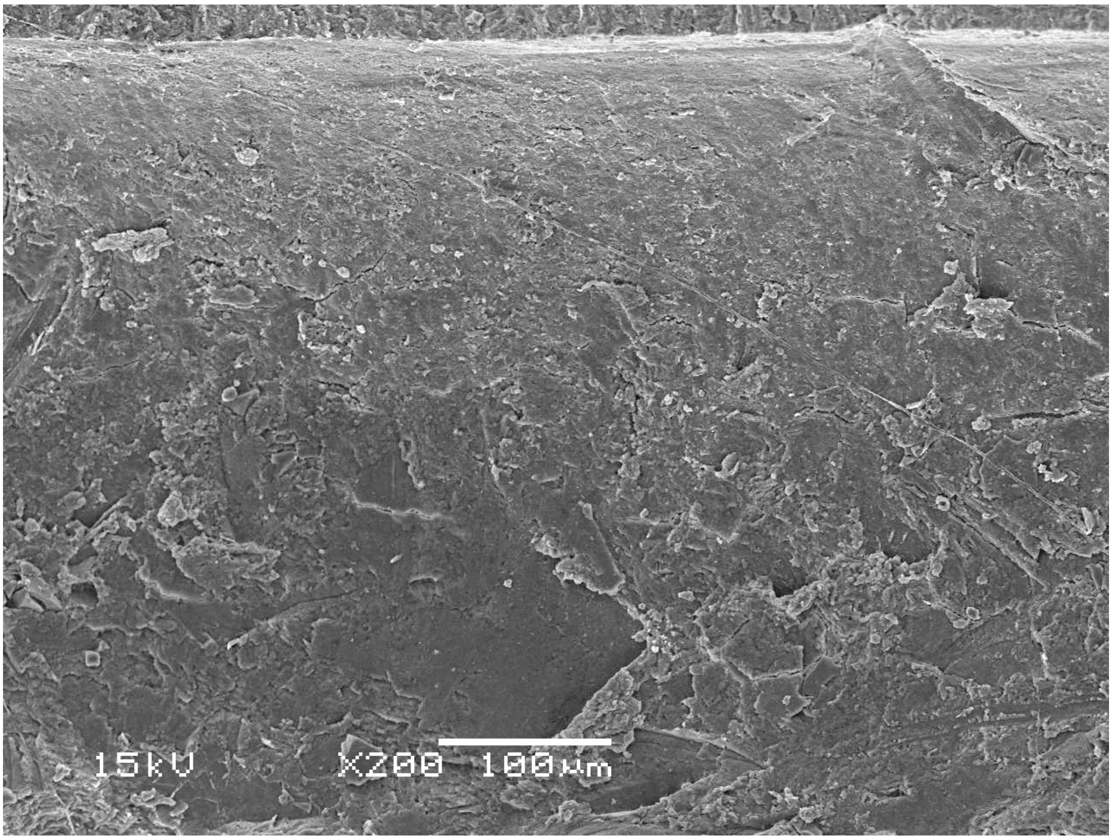


e)



Apical third

f)



g)

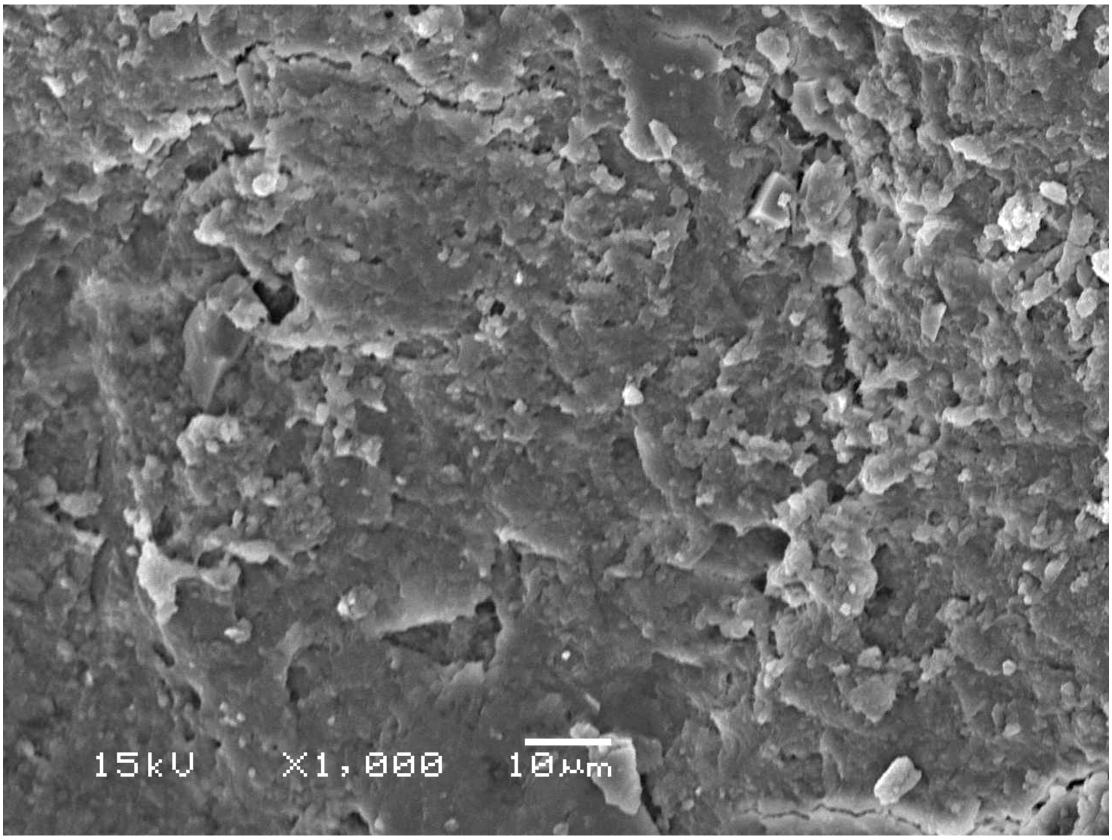
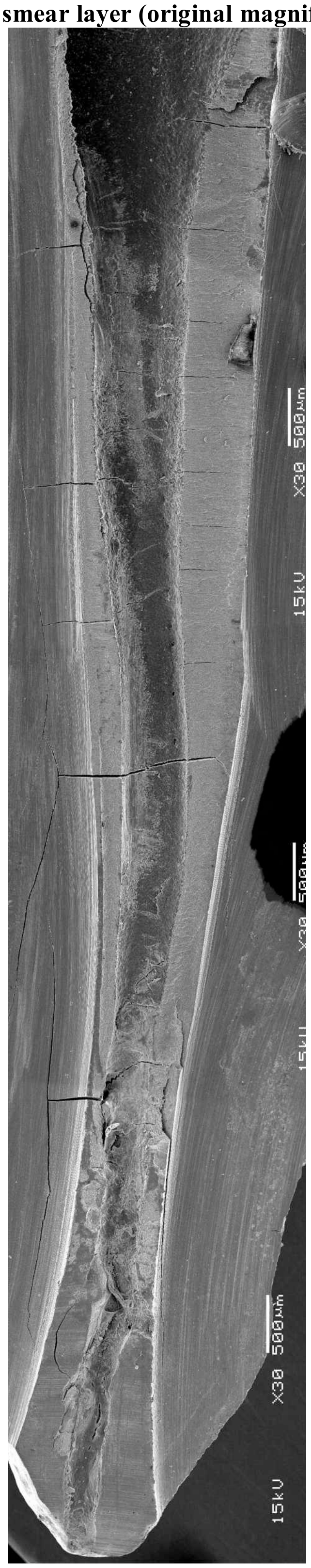


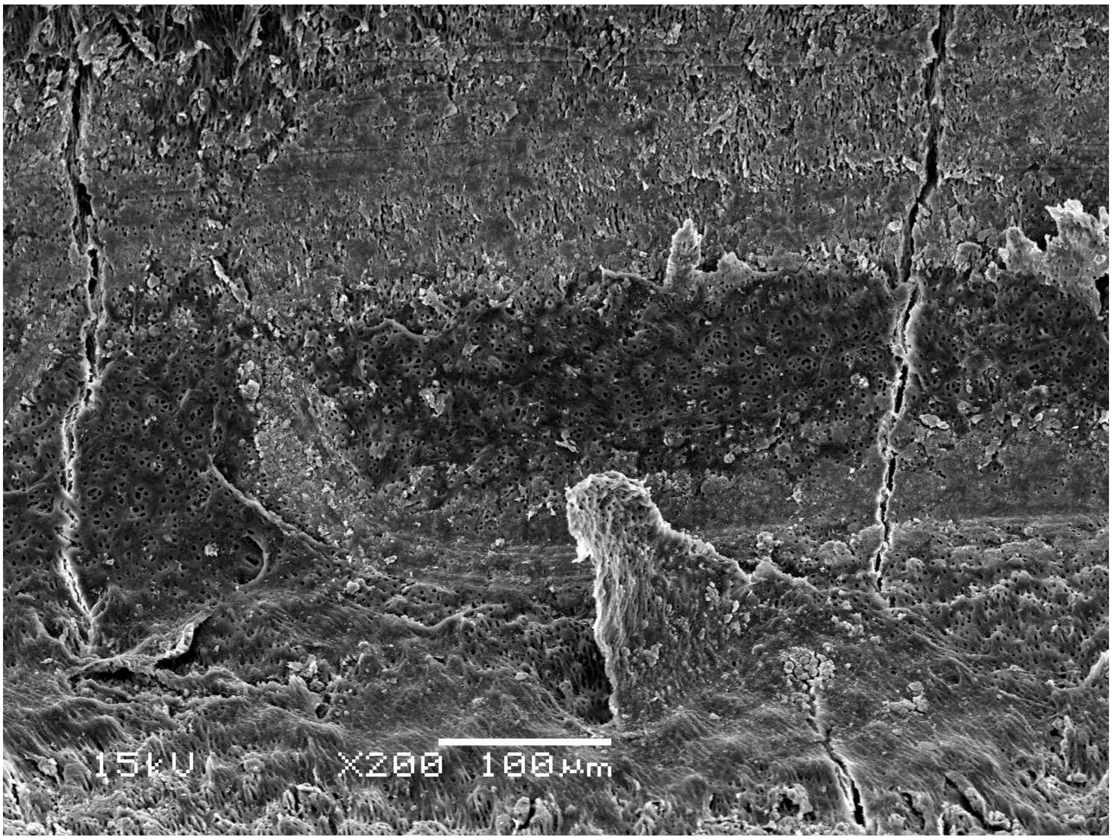
Figure 57 Photomicrographs record the SEM images of a representative tooth from the Unprepared Group (Specimen 57); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

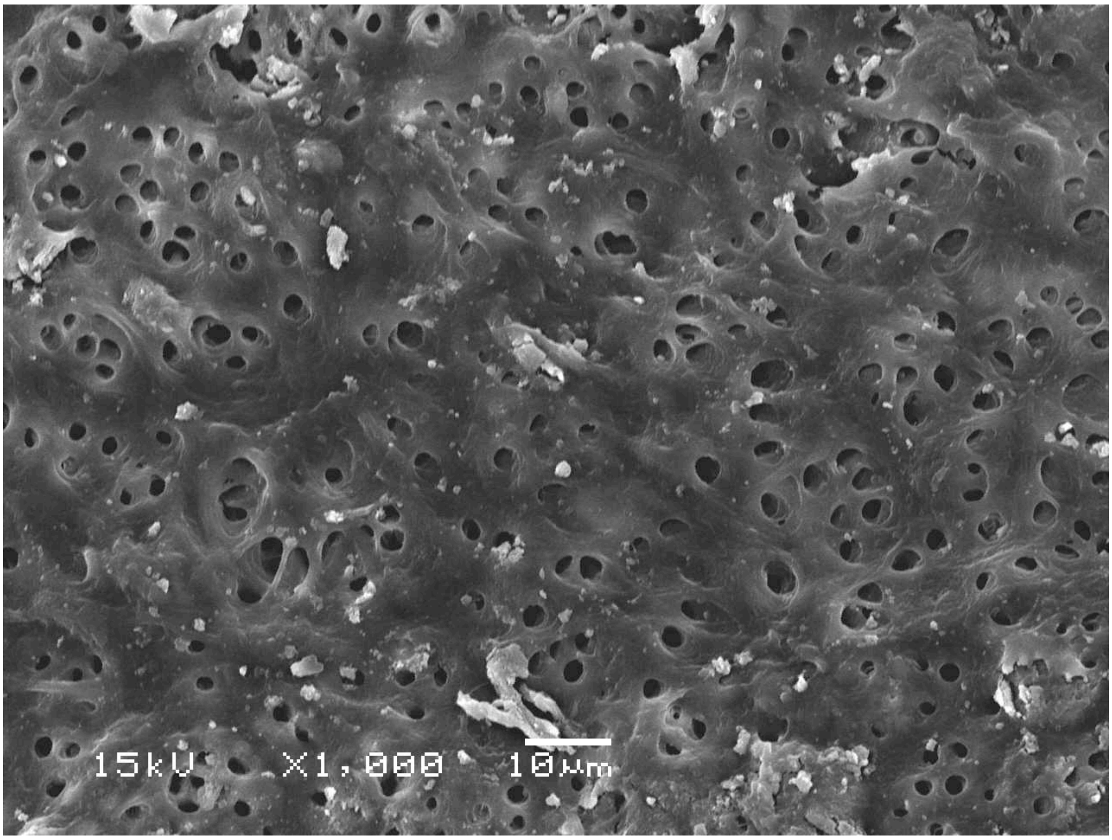


Coronal third

b)

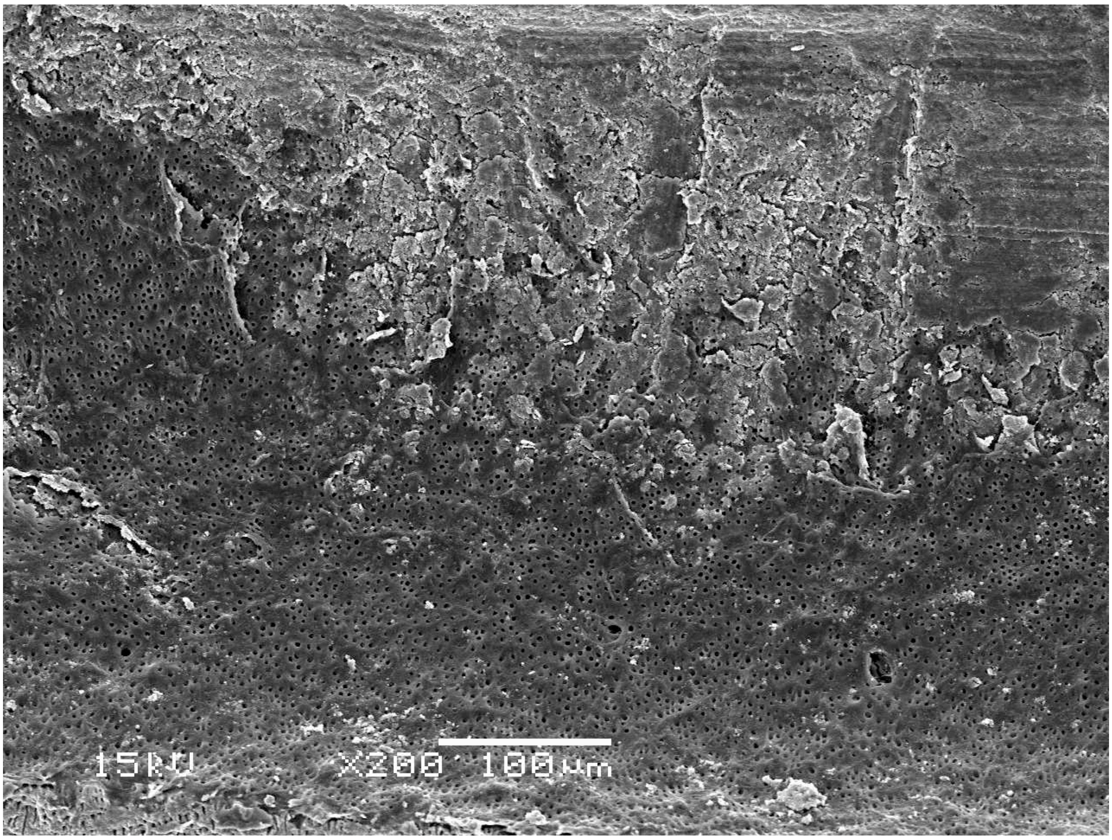


c)

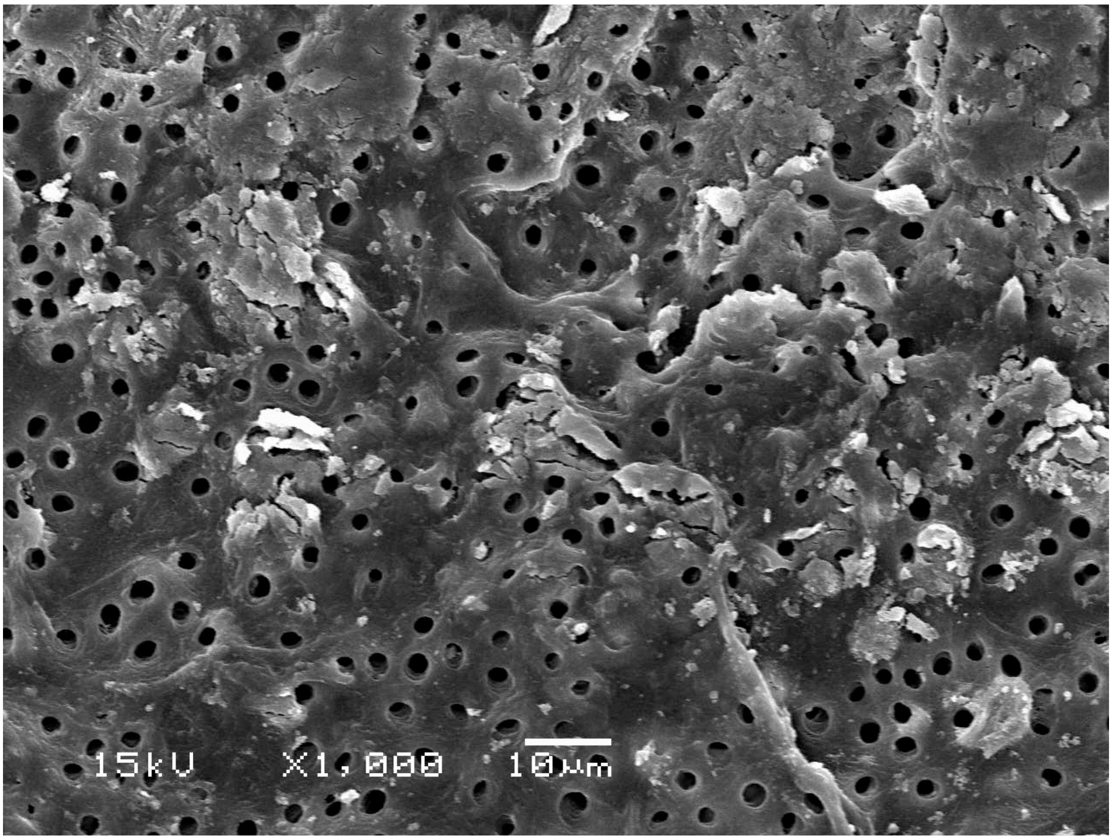


Mid third

d)

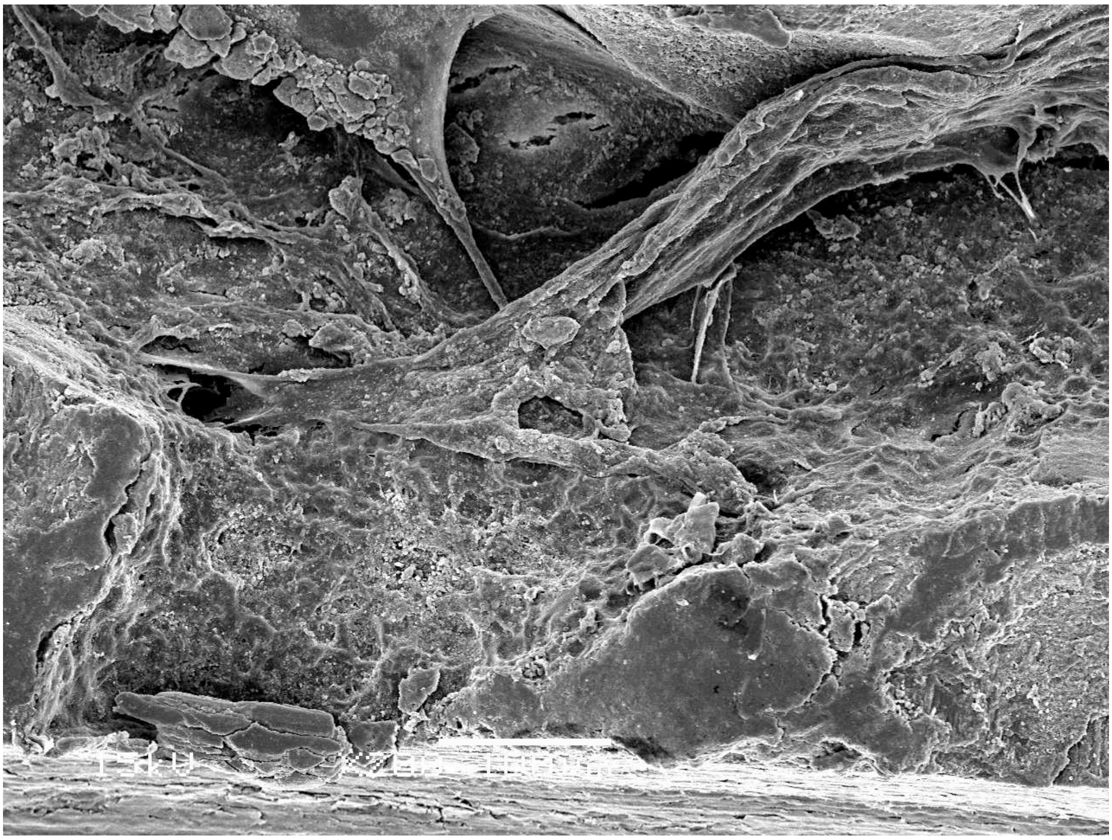


e)



Apical third

f)



g)

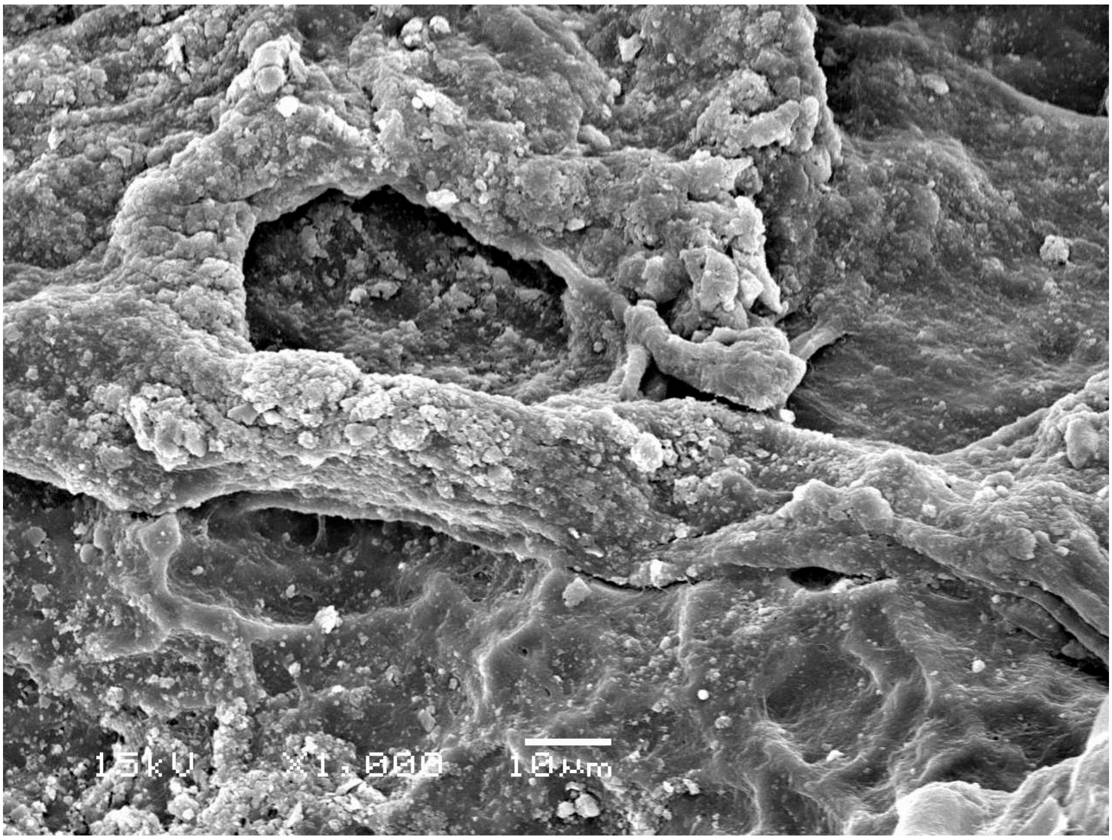
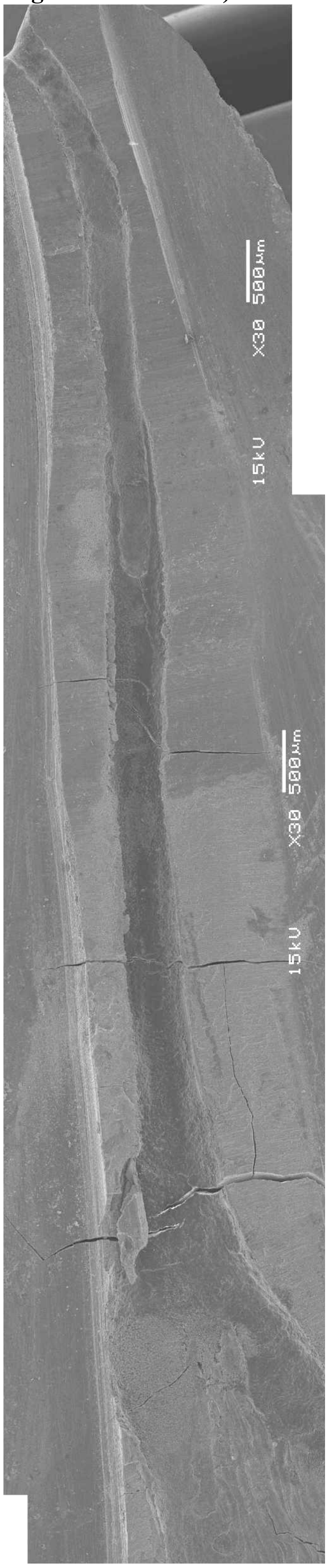


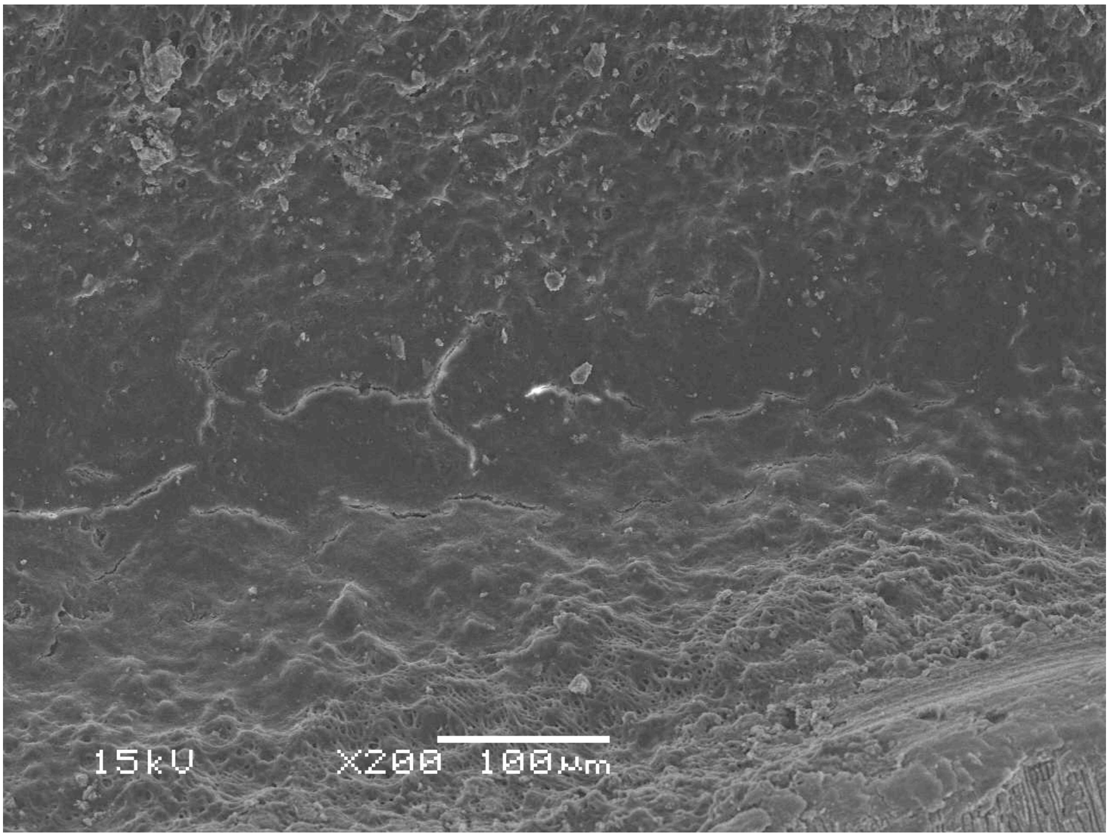
Figure 58 Photomicrographs record the SEM images of a representative tooth from the Unprepared Group (Specimen 151); a) composite photomicrograph (original magnification 30x); a), d) and f) were SEM images used to assess debris (original magnification 200x); c), e) and g) were SEM images used to assess smear layer (original magnification 1000x).

a)

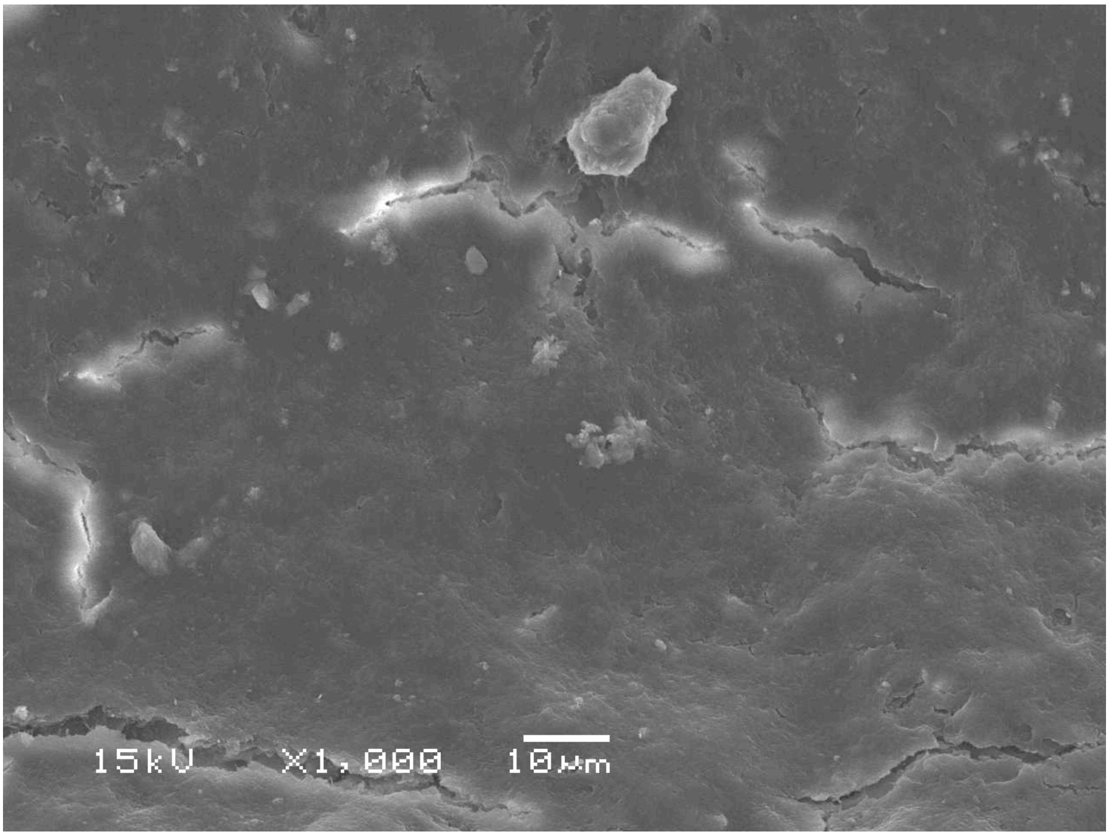


Coronal third

b)

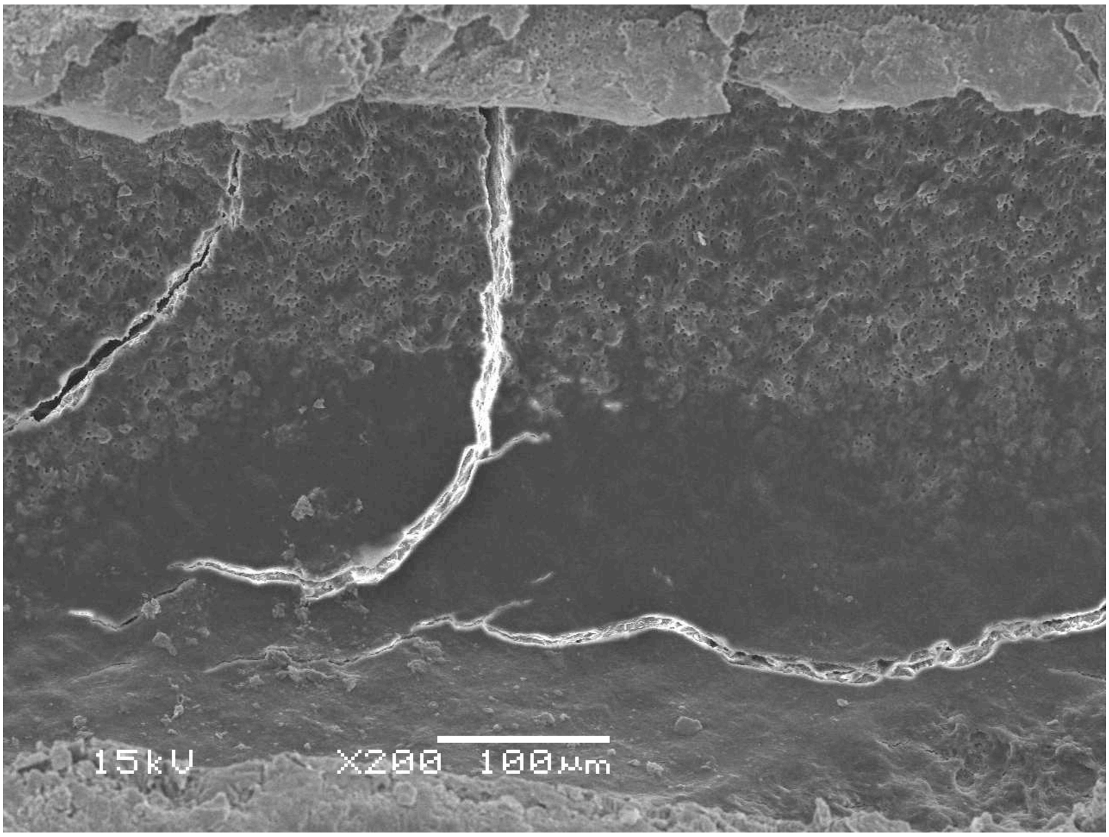


c)

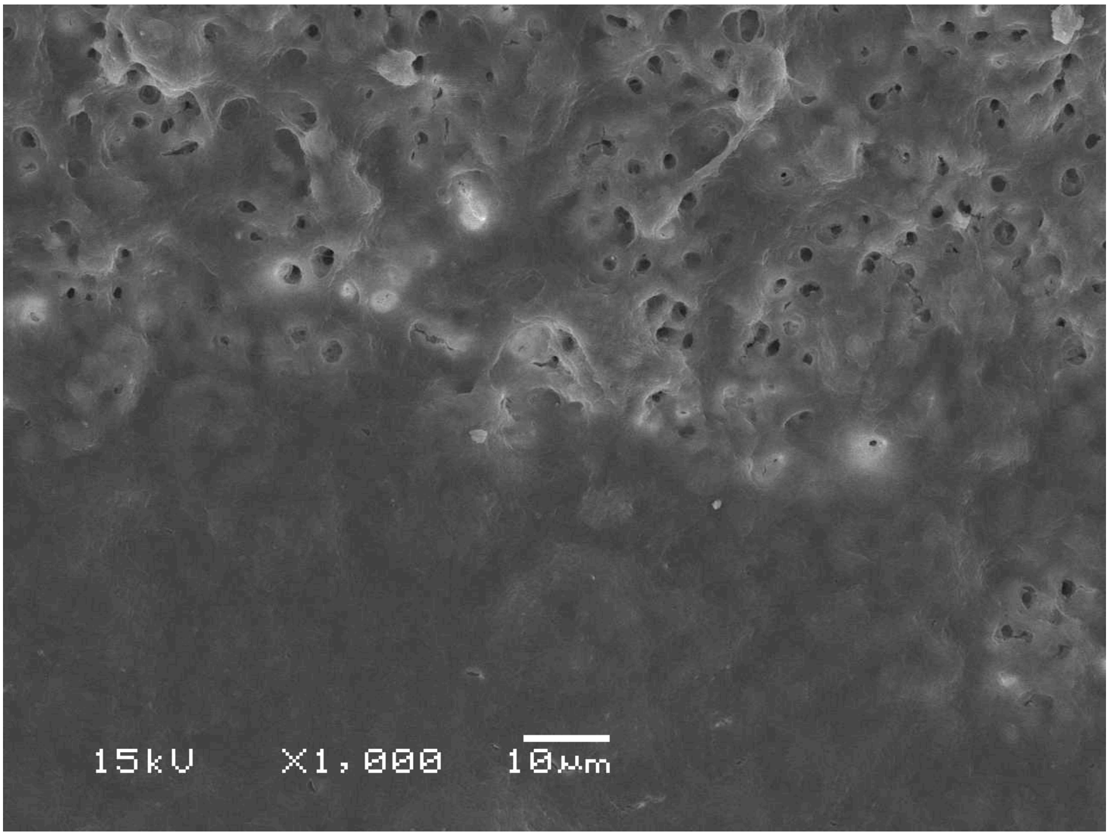


Mid third

d)

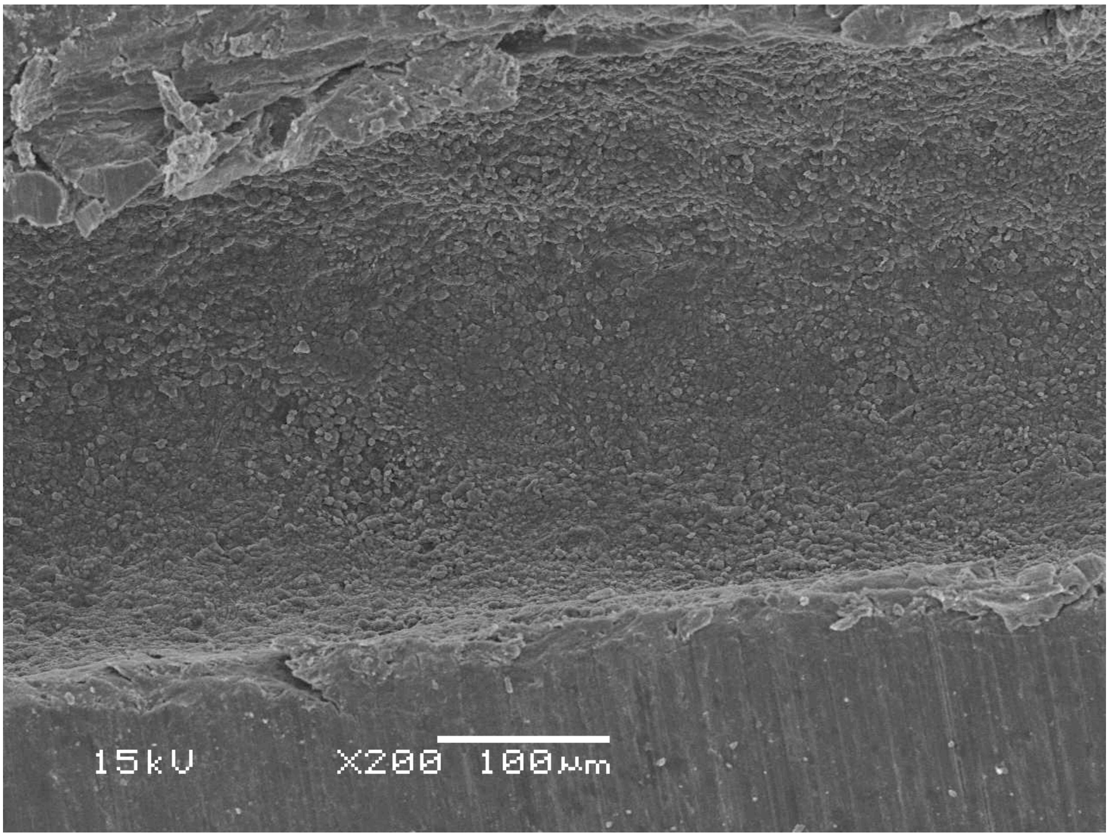


e)

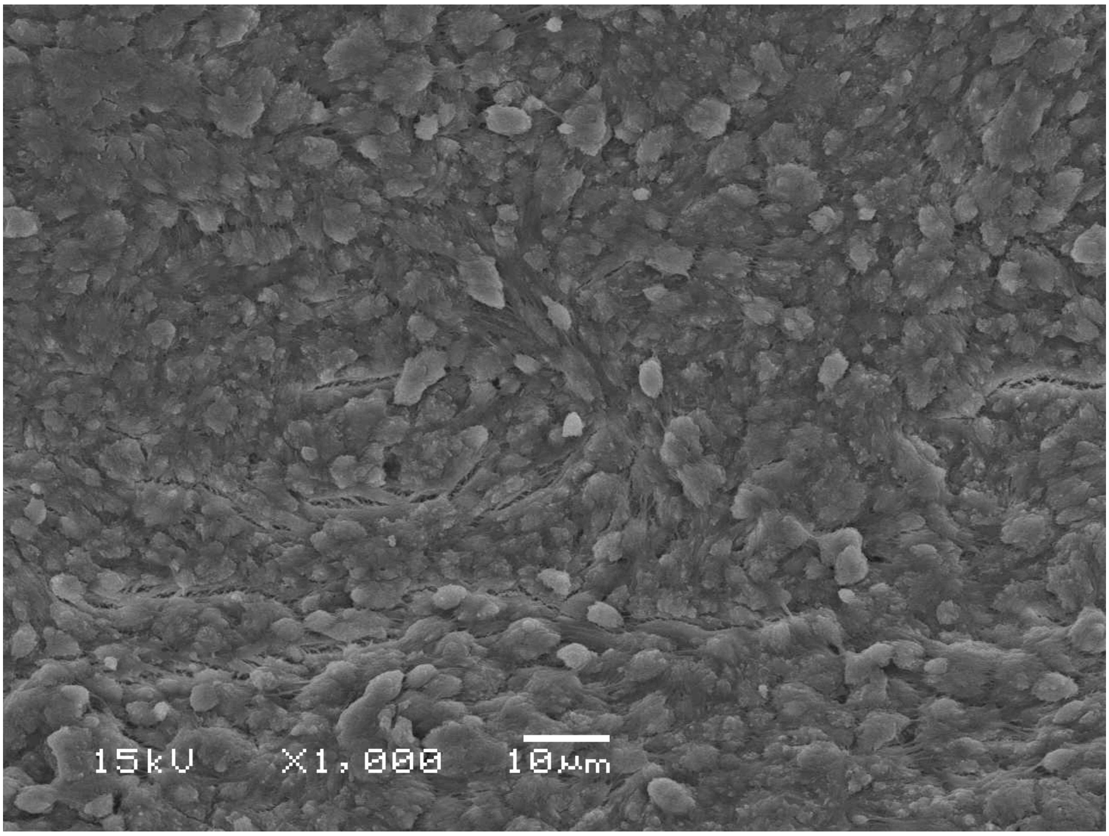


Apical third

f)



g)



Appendix 8 Study 1 data

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	5	1	NiTi	94	BM	0	1	1	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	5	1	NiTi	94	GW	0	1	1	1	0	1	1	1	1	1	1	1	1	11	2	2	2	4
1	5	1	NiTi	94	RH	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	11	1	NiTi	15	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	11	1	NiTi	15	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	11	1	NiTi	15	RH	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	17	1	NiTi	90	BM	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
1	17	1	NiTi	90	GW	1	1	1	1	1	1	0	0	0	1	0	1	1	9	3	3	0	3
1	17	1	NiTi	90	RH	1	1	1	1	1	1	0	0	0	1	1	1	1	10	3	3	0	4
1	26	1	NiTi	86	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	26	1	NiTi	86	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	26	1	NiTi	86	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	32	1	NiTi	57	BM	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	32	1	NiTi	57	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	32	1	NiTi	57	RH	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	37	1	NiTi	80	BM	0	0	0	1	1	1	2	1	0	0	1	1	1	9	0	3	1	3

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	37	1	NiTi	80	GW	1	0	0	1	1	1	0	1	1	1	1	1	1	10	1	3	2	4
1	37	1	NiTi	80	RH	1	0	0	1	1	0	0	1	1	1	1	1	1	9	1	2	2	4
1	41	1	NiTi	65	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	41	1	NiTi	65	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	41	1	NiTi	65	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	46	1	NiTi	24	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	46	1	NiTi	24	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	46	1	NiTi	24	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	52	1	NiTi	73	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	52	1	NiTi	73	GW	1	1	0	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
1	52	1	NiTi	73	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	58	1	NiTi	72	BM	1	0	1	1	1	1	0	1	1	1	0	1	1	10	2	3	2	3
1	58	1	NiTi	72	GW	1	0	1	1	1	1	0	1	1	1	1	1	1	11	2	3	2	4
1	58	1	NiTi	72	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	69	1	NiTi	17	BM	1	1	1	1	1	0	0	1	1	1	1	1	0	10	3	2	2	3
1	69	1	NiTi	17	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	69	1	NiTi	17	RH	1	1	1	1	1	1	0	0	1	1	1	1	1	11	3	3	1	4
1	75	1	NiTi	19	BM	0	0	0	1	1	1	1	1	1	1	1	1	1	10	0	3	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	75	1	NiTi	19	GW	0	1	1	1	1	1	1	0	0	1	0	1	1	9	2	3	0	3
1	75	1	NiTi	19	RH	0	1	1	1	1	1	0	1	1	1	1	1	1	11	2	3	2	4
1	85	1	NiTi	76	BM	1	1	1	1	0	0	2	0	0	1	1	1	1	10	3	1	0	4
1	85	1	NiTi	76	GW	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
1	85	1	NiTi	76	RH	1	0	1	1	1	1	2	0	0	1	1	1	1	11	2	3	0	4
1	90	1	NiTi	92	BM	1	1	1	1	1	0	0	1	1	1	1	1	1	11	3	2	2	4
1	90	1	NiTi	92	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	90	1	NiTi	92	RH	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	102	1	NiTi	14	BM	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	102	1	NiTi	14	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	102	1	NiTi	14	RH	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
1	107	1	NiTi	60	BM	1	1	0	1	1	1	1	0	0	1	1	1	1	10	2	3	0	4
1	107	1	NiTi	60	GW	1	1	0	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
1	107	1	NiTi	60	RH	1	1	0	1	0	1	0	1	1	1	1	1	1	10	2	2	2	4
1	112	1	NiTi	5	BM	1	1	1	1	1	1	1	1	1	1	0	1	1	12	3	3	2	3
1	112	1	NiTi	5	GW	1	0	0	1	1	1	0	1	0	1	1	1	1	9	1	3	1	4
1	112	1	NiTi	5	RH	1	1	1	1	1	1	0	0	0	1	1	1	1	10	3	3	0	4
1	116	1	NiTi	75	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	116	1	NiTi	75	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	116	1	NiTi	75	RH	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
1	120	1	NiTi	7	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	120	1	NiTi	7	GW	0	1	0	1	1	1	2	1	1	1	1	1	1	12	1	3	2	4
1	120	1	NiTi	7	RH	0	1	0	1	1	1	1	1	1	1	1	1	1	11	1	3	2	4
1	130	1	NiTi	58	BM	0	0	1	1	1	1	2	1	1	1	1	1	1	12	1	3	2	4
1	130	1	NiTi	58	GW	0	1	1	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	130	1	NiTi	58	RH	0	1	1	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
1	138	1	NiTi	51	BM	0	1	1	1	1	1	2	0	1	1	1	1	1	12	2	3	1	4
1	138	1	NiTi	51	GW	0	1	1	0	1	1	2	1	1	1	1	1	1	12	2	2	2	4
1	138	1	NiTi	51	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	142	1	NiTi	71	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	142	1	NiTi	71	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	142	1	NiTi	71	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	147	1	NiTi	53	BM	1	1	1	1	1	1	2	1	1	0	1	1	1	13	3	3	2	3
1	147	1	NiTi	53	GW	1	1	0	1	1	1	2	0	1	0	1	1	1	11	2	3	1	3
1	147	1	NiTi	53	RH	1	1	0	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
1	152	1	NiTi	12	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	152	1	NiTi	12	GW	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	152	1	NiTi	12	RH	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	158	1	NiTi	55	BM	0	1	1	0	1	1	0	1	1	0	0	1	1	8	2	2	2	2
1	158	1	NiTi	55	GW	0	1	1	1	1	1	0	0	0	0	0	1	1	7	2	3	0	2
1	158	1	NiTi	55	RH	0	1	1	1	1	1	0	1	0	0	0	1	1	8	2	3	1	2
1	1	2	Er:YAG	85	BM	0	0	1	0	0	1	2	0	1	1	1	0	0	7	1	1	1	2
1	1	2	Er:YAG	85	GW	0	0	0	0	0	0	2	0	0	0	1	0	0	3	0	0	0	1
1	1	2	Er:YAG	85	RH	1	1	1	0	0	1	2	0	0	1	1	0	0	8	3	1	0	2
1	6	2	Er:YAG	6	BM	0	0	0	0	0	0	2	0	1	1	1	0	1	6	0	0	1	3
1	6	2	Er:YAG	6	GW	0	0	0	0	0	0	1	0	0	0	1	0	1	3	0	0	0	2
1	6	2	Er:YAG	6	RH	0	0	1	0	0	0	0	0	0	1	1	0	1	4	1	0	0	3
1	12	2	Er:YAG	8	BM	0	0	0	0	0	0	2	0	0	1	0	0	1	4	0	0	0	2
1	12	2	Er:YAG	8	GW	0	1	1	0	0	0	2	0	0	1	0	0	1	6	2	0	0	2
1	12	2	Er:YAG	8	RH	0	1	1	0	0	0	0	0	0	1	1	1	1	6	2	0	0	4
1	20	2	Er:YAG	21	BM	0	0	0	1	1	1	2	0	0	1	1	1	1	9	0	3	0	4
1	20	2	Er:YAG	21	GW	0	0	1	1	1	1	2	1	0	1	1	1	1	11	1	3	1	4
1	20	2	Er:YAG	21	RH	0	0	0	1	1	1	2	1	1	1	1	1	1	11	0	3	2	4
1	28	2	Er:YAG	23	BM	0	0	0	1	1	0	2	0	0	1	1	1	1	8	0	2	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	28	2	Er:YAG	23	GW	0	1	0	1	1	0	2	0	0	0	1	1	1	8	1	2	0	3
1	28	2	Er:YAG	23	RH	1	1	0	0	1	1	2	0	0	0	1	1	1	9	2	2	0	3
1	34	2	Er:YAG	59	BM	0	0	0	0	0	0	2	0	0	0	1	0	1	4	0	0	0	2
1	34	2	Er:YAG	59	GW	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
1	34	2	Er:YAG	59	RH	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
1	38	2	Er:YAG	89	BM	0	0	1	0	1	1	2	0	0	1	0	1	1	8	1	2	0	3
1	38	2	Er:YAG	89	GW	0	1	0	0	0	0	0	0	0	0	1	0	1	3	1	0	0	2
1	38	2	Er:YAG	89	RH	1	1	1	0	0	1	2	0	0	1	0	1	1	9	3	1	0	3
1	42	2	Er:YAG	96	BM	0	0	1	0	0	1	2	0	0	1	1	1	1	8	1	1	0	4
1	42	2	Er:YAG	96	GW	0	0	1	0	0	1	2	1	1	1	1	1	1	10	1	1	2	4
1	42	2	Er:YAG	96	RH	1	0	0	0	0	0	1	1	0	1	1	1	1	7	1	0	1	4
1	47	2	Er:YAG	49	BM	0	0	0	0	1	0	2	0	1	1	0	1	1	7	0	1	1	3
1	47	2	Er:YAG	49	GW	0	0	1	0	0	0	2	1	0	1	1	1	1	8	1	0	1	4
1	47	2	Er:YAG	49	RH	0	0	0	0	0	0	2	0	1	1	1	1	1	7	0	0	1	4
1	54	2	Er:YAG	36	BM	0	0	0	0	0	0	0	0	0	1	0	1	1	3	0	0	0	3
1	54	2	Er:YAG	36	GW	0	0	0	0	0	0	1	0	0	1	0	0	1	3	0	0	0	2
1	54	2	Er:YAG	36	RH	0	1	0	0	0	0	0	0	0	1	1	0	1	4	1	0	0	3
1	59	2	Er:YAG	16	BM	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	2

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	59	2	Er:YAG	16	GW	0	0	1	0	0	0	1	0	0	1	1	0	1	5	1	0	0	3
1	59	2	Er:YAG	16	RH	0	0	0	0	0	0	0	0	0	1	1	0	1	3	0	0	0	3
1	76	2	Er:YAG	61	BM	0	0	0	0	0	0	0	0	0	1	0	1	1	3	0	0	0	3
1	76	2	Er:YAG	61	GW	0	0	0	0	0	0	1	0	0	1	0	0	1	3	0	0	0	2
1	76	2	Er:YAG	61	RH	0	1	0	0	0	0	0	0	0	1	0	0	1	3	1	0	0	2
1	86	2	Er:YAG	10	BM	0	0	0	0	0	0	2	0	0	1	0	0	1	4	0	0	0	2
1	86	2	Er:YAG	10	GW	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
1	86	2	Er:YAG	10	RH	0	0	0	0	0	0	2	0	0	0	0	0	1	3	0	0	0	1
1	91	2	Er:YAG	9	BM	0	0	0	1	1	1	2	1	0	1	1	1	1	10	0	3	1	4
1	91	2	Er:YAG	9	GW	0	0	0	1	1	1	2	1	1	1	1	1	1	11	0	3	2	4
1	91	2	Er:YAG	9	RH	0	1	0	1	1	1	2	1	1	1	1	1	1	12	1	3	2	4
1	103	2	Er:YAG	52	BM	0	0	0	1	1	1	2	1	0	1	1	1	1	10	0	3	1	4
1	103	2	Er:YAG	52	GW	1	0	1	1	1	0	2	1	0	1	1	1	1	11	2	2	1	4
1	103	2	Er:YAG	52	RH	1	0	0	0	0	1	1	1	0	1	1	1	1	8	1	1	1	4
1	108	2	Er:YAG	29	BM	0	0	0	1	0	0	2	0	0	0	1	1	1	6	0	1	0	3
1	108	2	Er:YAG	29	GW	0	0	0	1	1	1	2	0	0	0	1	1	1	8	0	3	0	3
1	108	2	Er:YAG	29	RH	0	0	0	1	0	0	2	0	0	0	1	0	1	5	0	1	0	2
1	113	2	Er:YAG	64	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	113	2	Er:YAG	64	GW	0	0	0	0	0	0	1	1	0	1	1	1	1	6	0	0	1	4
1	113	2	Er:YAG	64	RH	0	0	1	0	0	0	0	0	1	1	1	1	1	6	1	0	1	4
1	117	2	Er:YAG	68	BM	0	0	0	0	0	0	2	0	1	0	1	0	1	5	0	0	1	2
1	117	2	Er:YAG	68	GW	0	0	1	0	0	0	1	0	0	0	0	0	1	3	1	0	0	1
1	117	2	Er:YAG	68	RH	1	1	1	0	0	1	0	0	0	1	1	0	1	7	3	1	0	3
1	123	2	Er:YAG	88	BM	0	0	1	0	0	0	2	1	1	0	1	0	1	7	1	0	2	2
1	123	2	Er:YAG	88	GW	0	1	1	0	0	0	1	0	0	0	1	0	1	5	2	0	0	2
1	123	2	Er:YAG	88	RH	0	1	1	1	1	1	2	0	0	1	1	0	1	10	2	3	0	3
1	132	2	Er:YAG	48	BM	0	0	0	0	0	1	2	1	1	1	1	1	1	9	0	1	2	4
1	132	2	Er:YAG	48	GW	0	0	0	1	1	0	2	0	0	0	0	1	1	6	0	2	0	2
1	132	2	Er:YAG	48	RH	1	0	0	0	0	0	0	0	0	1	1	1	1	5	1	0	0	4
1	139	2	Er:YAG	2	BM	0	0	0	0	0	1	1	1	0	1	1	1	1	7	0	1	1	4
1	139	2	Er:YAG	2	GW	0	0	0	0	0	1	0	0	0	1	1	0	1	4	0	1	0	3
1	139	2	Er:YAG	2	RH	0	1	0	1	1	1	0	0	0	1	1	0	1	7	1	3	0	3
1	143	2	Er:YAG	81	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
1	143	2	Er:YAG	81	GW	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
1	143	2	Er:YAG	81	RH	1	0	0	0	0	0	0	0	0	1	1	1	1	5	1	0	0	4
1	148	2	Er:YAG	4	BM	0	0	0	1	0	1	0	0	1	1	1	1	1	7	0	2	1	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	148	2	Er:YAG	4	GW	1	1	1	0	0	0	0	0	0	1	1	0	1	6	3	0	0	3
1	148	2	Er:YAG	4	RH	1	1	1	1	1	1	1	0	1	1	1	1	1	12	3	3	1	4
1	153	2	Er:YAG	11	BM	0	0	0	1	1	0	2	1	1	1	1	1	1	10	0	2	2	4
1	153	2	Er:YAG	11	GW	1	0	0	0	0	1	2	1	0	1	1	1	1	9	1	1	1	4
1	153	2	Er:YAG	11	RH	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	159	2	Er:YAG	47	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
1	159	2	Er:YAG	47	GW	0	0	0	0	0	0	0	1	0	1	1	1	1	5	0	0	1	4
1	159	2	Er:YAG	47	RH	0	0	0	0	0	0	0	0	0	1	1	0	1	3	0	0	0	3
1	3	3	Er,Cr:YSGG	67	BM	0	1	1	0	0	1	2	0	1	1	1	1	1	10	2	1	1	4
1	3	3	Er,Cr:YSGG	67	GW	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
1	3	3	Er,Cr:YSGG	67	RH	0	0	1	0	0	1	2	0	0	1	0	1	1	7	1	1	0	3
1	13	3	Er,Cr:YSGG	25	BM	0	0	0	1	1	1	2	1	0	1	1	1	1	10	0	3	1	4
1	13	3	Er,Cr:YSGG	25	GW	0	0	0	1	1	1	2	1	1	1	1	1	1	11	0	3	2	4
1	13	3	Er,Cr:YSGG	25	RH	0	0	0	1	0	0	2	1	1	1	1	1	1	9	0	1	2	4
1	21	3	Er,Cr:YSGG	77	BM	0	0	1	1	1	1	2	0	0	1	1	1	1	10	1	3	0	4
1	21	3	Er,Cr:YSGG	77	GW	0	1	1	1	1	1	0	1	0	1	0	1	1	9	2	3	1	3
1	21	3	Er,Cr:YSGG	77	RH	1	1	1	0	0	1	0	1	0	1	1	1	1	9	3	1	1	4
1	29	3	Er,Cr:YSGG	93	BM	0	0	0	0	1	0	2	0	0	1	1	1	1	7	0	1	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	29	3	Er,Cr:YSGG	93	GW	1	1	1	0	0	1	2	0	0	1	1	1	1	10	3	1	0	4
1	29	3	Er,Cr:YSGG	93	RH	1	1	0	0	0	0	2	0	0	1	1	0	1	7	2	0	0	3
1	35	3	Er,Cr:YSGG	32	BM	0	0	0	0	1	1	0	0	0	1	0	1	0	4	0	2	0	2
1	35	3	Er,Cr:YSGG	32	GW	0	0	0	0	1	1	1	1	1	1	1	1	1	9	0	2	2	4
1	35	3	Er,Cr:YSGG	32	RH	0	1	1	0	0	1	0	0	0	1	1	1	1	7	2	1	0	4
1	39	3	Er,Cr:YSGG	69	BM	0	0	0	0	0	1	2	0	1	1	1	1	1	8	0	1	1	4
1	39	3	Er,Cr:YSGG	69	GW	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
1	39	3	Er,Cr:YSGG	69	RH	0	0	1	0	0	1	2	0	0	1	1	1	1	8	1	1	0	4
1	44	3	Er,Cr:YSGG	43	BM	0	0	1	0	0	1	2	0	1	1	1	1	1	9	1	1	1	4
1	44	3	Er,Cr:YSGG	43	GW	0	0	1	0	0	1	1	1	0	0	0	1	1	6	1	1	1	2
1	44	3	Er,Cr:YSGG	43	RH	1	1	1	0	1	1	1	1	1	1	1	1	1	12	3	2	2	4
1	56	3	Er,Cr:YSGG	50	BM	0	0	0	0	1	0	1	0	0	1	1	1	1	6	0	1	0	4
1	56	3	Er,Cr:YSGG	50	GW	0	0	1	1	1	1	1	1	1	1	1	1	1	11	1	3	2	4
1	56	3	Er,Cr:YSGG	50	RH	0	1	1	0	0	1	0	1	1	1	1	1	1	9	2	1	2	4
1	60	3	Er,Cr:YSGG	74	BM	0	1	1	1	1	1	2	1	0	1	1	1	1	12	2	3	1	4
1	60	3	Er,Cr:YSGG	74	GW	1	1	1	1	1	0	2	1	0	0	1	1	1	11	3	2	1	3
1	60	3	Er,Cr:YSGG	74	RH	1	1	1	0	1	1	2	1	0	1	1	1	1	12	3	2	1	4
1	72	3	Er,Cr:YSGG	13	BM	0	1	1	0	0	1	1	0	0	1	1	1	1	8	2	1	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	72	3	Er,Cr:YSGG	13	GW	0	1	1	1	1	1	0	1	0	1	1	1	1	10	2	3	1	4
1	72	3	Er,Cr:YSGG	13	RH	0	1	1	1	1	1	0	1	0	1	1	1	1	10	2	3	1	4
1	87	3	Er,Cr:YSGG	28	BM	0	0	0	1	1	0	2	0	1	1	1	1	1	9	0	2	1	4
1	87	3	Er,Cr:YSGG	28	GW	1	1	1	0	1	1	1	1	1	1	1	1	1	12	3	2	2	4
1	87	3	Er,Cr:YSGG	28	RH	1	1	1	0	1	0	0	1	1	1	1	1	1	10	3	1	2	4
1	92	3	Er,Cr:YSGG	41	BM	0	0	0	0	1	1	0	0	0	1	1	1	1	6	0	2	0	4
1	92	3	Er,Cr:YSGG	41	GW	0	1	1	0	1	1	0	1	0	1	1	1	1	9	2	2	1	4
1	92	3	Er,Cr:YSGG	41	RH	1	1	1	0	1	1	0	0	0	1	1	1	1	9	3	2	0	4
1	104	3	Er,Cr:YSGG	38	BM	0	1	1	0	0	1	1	0	0	1	0	1	1	7	2	1	0	3
1	104	3	Er,Cr:YSGG	38	GW	1	1	1	1	1	1	1	1	0	1	1	1	1	12	3	3	1	4
1	104	3	Er,Cr:YSGG	38	RH	1	1	1	1	1	1	0	1	1	1	0	1	1	11	3	3	2	3
1	109	3	Er,Cr:YSGG	27	BM	0	0	1	0	1	1	2	0	0	1	0	1	1	8	1	2	0	3
1	109	3	Er,Cr:YSGG	27	GW	0	1	1	0	1	1	2	1	0	1	1	1	1	11	2	2	1	4
1	109	3	Er,Cr:YSGG	27	RH	0	1	1	0	1	1	2	1	1	1	1	1	1	12	2	2	2	4
1	114	3	Er,Cr:YSGG	34	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	114	3	Er,Cr:YSGG	34	GW	1	1	1	1	1	1	0	1	0	1	1	1	1	11	3	3	1	4
1	114	3	Er,Cr:YSGG	34	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	118	3	Er,Cr:YSGG	95	BM	0	0	0	0	0	1	1	1	1	1	1	1	1	8	0	1	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	118	3	Er,Cr:YSGG	95	GW	0	0	0	0	1	1	0	1	1	1	1	1	1	8	0	2	2	4
1	118	3	Er,Cr:YSGG	95	RH	0	0	0	1	0	0	0	1	1	1	1	0	1	6	0	1	2	3
1	126	3	Er,Cr:YSGG	42	BM	0	0	1	1	1	1	1	0	0	1	1	1	1	9	1	3	0	4
1	126	3	Er,Cr:YSGG	42	GW	0	1	1	0	1	1	0	1	1	1	1	1	1	10	2	2	2	4
1	126	3	Er,Cr:YSGG	42	RH	1	1	1	0	1	1	0	1	0	1	1	1	1	10	3	2	1	4
1	134	3	Er,Cr:YSGG	70	BM	0	0	0	0	0	1	2	0	0	1	1	1	1	7	0	1	0	4
1	134	3	Er,Cr:YSGG	70	GW	0	0	1	0	0	1	2	0	0	1	1	1	1	8	1	1	0	4
1	134	3	Er,Cr:YSGG	70	RH	0	0	1	0	0	1	0	0	0	1	1	1	1	6	1	1	0	4
1	140	3	Er,Cr:YSGG	56	BM	0	1	0	1	1	0	2	1	1	1	1	1	1	11	1	2	2	4
1	140	3	Er,Cr:YSGG	56	GW	0	1	1	0	1	1	2	1	1	1	1	1	1	12	2	2	2	4
1	140	3	Er,Cr:YSGG	56	RH	0	1	1	0	1	1	1	1	0	1	1	1	1	10	2	2	1	4
1	144	3	Er,Cr:YSGG	45	BM	0	0	0	1	0	1	2	0	1	1	1	1	1	9	0	2	1	4
1	144	3	Er,Cr:YSGG	45	GW	0	1	1	0	0	1	2	1	0	1	0	1	1	9	2	1	1	3
1	144	3	Er,Cr:YSGG	45	RH	0	0	1	0	0	0	0	0	0	1	0	1	1	4	1	0	0	3
1	149	3	Er,Cr:YSGG	46	BM	0	0	0	1	1	1	1	1	1	1	1	1	1	10	0	3	2	4
1	149	3	Er,Cr:YSGG	46	GW	0	1	1	1	1	1	1	1	0	1	1	1	1	11	2	3	1	4
1	149	3	Er,Cr:YSGG	46	RH	0	0	1	0	1	1	0	0	0	1	1	1	1	7	1	2	0	4
1	156	3	Er,Cr:YSGG	91	BM	0	0	0	0	0	1	2	0	1	1	1	1	1	8	0	1	1	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	156	3	Er,Cr:YSGG	91	GW	0	0	1	0	0	0	1	0	0	1	1	1	1	6	1	0	0	4
1	156	3	Er,Cr:YSGG	91	RH	0	0	0	0	0	1	1	0	0	1	1	1	1	6	0	1	0	4
1	160	3	Er,Cr:YSGG	40	BM	0	0	1	1	1	1	2	1	0	1	1	1	1	11	1	3	1	4
1	160	3	Er,Cr:YSGG	40	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	160	3	Er,Cr:YSGG	40	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
1	4	4	Unpreppared	33	BM	0	0	0	0	0	0	1	0	1	1	1	1	1	6	0	0	1	4
1	4	4	Unpreppared	33	GW	0	1	0	0	0	1	2	0	0	1	1	1	1	8	1	1	0	4
1	4	4	Unpreppared	33	RH	0	0	0	0	0	1	0	1	0	1	1	1	1	6	0	1	1	4
1	9	4	Unpreppared	26	BM	0	1	1	0	1	1	2	0	0	1	0	0	1	8	2	2	0	2
1	9	4	Unpreppared	26	GW	1	1	1	1	1	1	2	0	0	1	1	0	1	11	3	3	0	3
1	9	4	Unpreppared	26	RH	1	1	1	0	1	1	2	0	0	0	1	0	1	9	3	2	0	2
1	15	4	Unpreppared	35	BM	0	0	0	0	1	0	1	0	0	1	1	1	1	6	0	1	0	4
1	15	4	Unpreppared	35	GW	0	0	1	0	1	1	1	1	1	1	1	1	1	10	1	2	2	4
1	15	4	Unpreppared	35	RH	0	0	0	1	1	1	0	1	1	0	1	1	1	8	0	3	2	3
1	22	4	Unpreppared	78	BM	0	0	1	0	1	1	2	0	1	1	1	1	1	10	1	2	1	4
1	22	4	Unpreppared	78	GW	1	1	1	0	1	1	1	0	0	1	1	1	1	10	3	2	0	4
1	22	4	Unpreppared	78	RH	1	1	1	0	0	1	0	0	0	1	1	1	1	8	3	1	0	4
1	30	4	Unpreppared	18	BM	1	1	0	1	1	0	2	1	1	1	1	1	1	12	2	2	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	30	4	Unpreppared	18	GW	1	1	1	1	1	1	0	1	0	1	1	1	1	11	3	3	1	4
1	30	4	Unpreppared	18	RH	1	1	0	1	1	0	2	0	1	1	1	0	1	10	2	2	1	3
1	36	4	Unpreppared	44	BM	1	0	0	1	1	1	0	1	1	1	1	1	1	10	1	3	2	4
1	36	4	Unpreppared	44	GW	1	0	0	1	1	1	0	1	1	1	1	1	1	10	1	3	2	4
1	36	4	Unpreppared	44	RH	1	0	1	1	0	0	0	1	1	1	1	1	1	9	2	1	2	4
1	40	4	Unpreppared	30	BM	0	0	0	0	0	1	2	1	0	1	1	1	1	8	0	1	1	4
1	40	4	Unpreppared	30	GW	1	0	0	1	1	1	1	1	0	1	1	1	1	10	1	3	1	4
1	40	4	Unpreppared	30	RH	1	0	0	1	1	1	1	0	0	1	1	1	1	9	1	3	0	4
1	50	4	Unpreppared	66	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
1	50	4	Unpreppared	66	GW	0	1	0	0	1	0	0	1	0	1	1	1	1	7	1	1	1	4
1	50	4	Unpreppared	66	RH	0	1	0	0	0	0	0	0	0	1	1	1	1	5	1	0	0	4
1	57	4	Unpreppared	82	BM	0	0	0	1	0	0	1	0	0	1	1	1	1	6	0	1	0	4
1	57	4	Unpreppared	82	GW	1	1	0	1	1	0	0	1	0	1	1	1	1	9	2	2	1	4
1	57	4	Unpreppared	82	RH	1	1	0	0	1	0	0	0	0	1	1	1	1	7	2	1	0	4
1	65	4	Unpreppared	84	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
1	65	4	Unpreppared	84	GW	1	1	0	0	0	1	2	1	0	1	1	1	1	10	2	1	1	4
1	65	4	Unpreppared	84	RH	0	0	0	1	1	0	2	0	0	1	1	1	1	8	0	2	0	4
1	74	4	Unpreppared	31	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	74	4	Unpreppared	31	GW	1	1	0	1	1	1	0	1	0	1	1	1	1	10	2	3	1	4
1	74	4	Unpreppared	31	RH	1	1	1	1	1	0	0	1	1	1	1	1	1	11	3	2	2	4
1	83	4	Unpreppared	87	BM	0	1	1	0	0	0	1	0	0	1	1	1	1	7	2	0	0	4
1	83	4	Unpreppared	87	GW	0	1	0	0	1	1	1	1	0	1	1	1	1	9	1	2	1	4
1	83	4	Unpreppared	87	RH	1	0	0	0	0	0	0	0	0	1	1	0	1	4	1	0	0	3
1	89	4	Unpreppared	22	BM	0	1	0	0	1	1	2	1	1	1	1	1	1	11	1	2	2	4
1	89	4	Unpreppared	22	GW	0	0	0	0	0	1	0	1	0	1	1	1	1	6	0	1	1	4
1	89	4	Unpreppared	22	RH	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
1	97	4	Unpreppared	20	BM	0	0	0	0	1	0	0	0	0	1	1	1	1	5	0	1	0	4
1	97	4	Unpreppared	20	GW	0	0	1	1	1	1	0	1	0	1	1	1	1	9	1	3	1	4
1	97	4	Unpreppared	20	RH	0	0	1	0	1	1	0	1	1	1	1	1	1	9	1	2	2	4
1	106	4	Unpreppared	3	BM	0	0	0	1	1	1	2	1	1	1	1	1	1	11	0	3	2	4
1	106	4	Unpreppared	3	GW	0	0	0	0	0	0	0	1	1	1	1	1	1	6	0	0	2	4
1	106	4	Unpreppared	3	RH	0	0	0	1	1	1	0	0	1	1	1	1	1	8	0	3	1	4
1	110	4	Unpreppared	62	BM	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
1	110	4	Unpreppared	62	GW	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
1	110	4	Unpreppared	62	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
1	115	4	Unpreppared	1	BM	1	1	1	0	1	1	1	1	1	1	1	1	1	12	3	2	2	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	115	4	Unpreppared	1	GW	0	1	1	0	1	1	1	0	0	1	1	1	1	9	2	2	0	4
1	115	4	Unpreppared	1	RH	0	0	1	0	0	1	1	1	1	1	1	1	1	9	1	1	2	4
1	119	4	Unpreppared	79	BM	0	0	0	0	1	1	0	1	1	1	1	1	0	7	0	2	2	3
1	119	4	Unpreppared	79	GW	0	0	0	0	0	0	0	1	1	1	1	1	1	6	0	0	2	4
1	119	4	Unpreppared	79	RH	0	0	0	1	1	1	0	1	1	1	1	1	1	9	0	3	2	4
1	128	4	Unpreppared	83	BM	0	0	0	1	0	1	2	1	1	1	1	1	1	10	0	2	2	4
1	128	4	Unpreppared	83	GW	0	0	0	1	1	0	2	1	1	1	1	1	1	10	0	2	2	4
1	128	4	Unpreppared	83	RH	1	0	1	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
1	141	4	Unpreppared	39	BM	0	0	0	0	0	1	0	0	0	1	1	1	1	5	0	1	0	4
1	141	4	Unpreppared	39	GW	0	0	0	0	0	0	0	1	0	1	1	1	1	5	0	0	1	4
1	141	4	Unpreppared	39	RH	0	0	0	0	0	0	0	1	1	1	1	1	1	6	0	0	2	4
1	145	4	Unpreppared	63	BM	0	0	0	0	0	1	2	0	1	1	1	1	1	8	0	1	1	4
1	145	4	Unpreppared	63	GW	0	0	0	0	1	1	2	1	1	1	1	1	1	10	0	2	2	4
1	145	4	Unpreppared	63	RH	1	1	0	1	1	1	0	1	1	1	1	1	1	11	2	3	2	4
1	151	4	Unpreppared	54	BM	0	1	1	1	0	0	0	0	0	1	1	1	1	7	2	1	0	4
1	151	4	Unpreppared	54	GW	0	1	1	0	1	1	0	1	0	1	1	1	1	9	2	2	1	4
1	151	4	Unpreppared	54	RH	1	1	1	1	0	1	0	1	0	1	1	1	1	10	3	2	1	4
1	157	4	Unpreppared	37	BM	0	0	0	0	1	0	1	0	0	1	1	1	1	6	0	1	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
1	157	4	Unpreppared	37	GW	0	1	1	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
1	157	4	Unpreppared	37	RH	0	1	0	0	1	0	1	1	1	1	1	1	1	9	1	1	2	4
2	5	1	NiTi	63	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	5	1	NiTi	63	GW	0	0	1	1	0	1	1	1	1	1	1	1	1	10	1	2	2	4
2	5	1	NiTi	63	RH	1	1	1	1	1	1	1	1	0	1	1	1	1	12	3	3	1	4
2	11	1	NiTi	34	BM	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	11	1	NiTi	34	GW	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
2	11	1	NiTi	34	RH	1	1	0	1	1	1	2	1	0	1	1	1	1	12	2	3	1	4
2	17	1	NiTi	36	BM	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	17	1	NiTi	36	GW	1	1	1	1	1	1	0	0	0	1	0	1	1	9	3	3	0	3
2	17	1	NiTi	36	RH	1	1	1	0	1	1	0	1	0	1	1	1	1	10	3	2	1	4
2	26	1	NiTi	44	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	26	1	NiTi	44	GW	1	1	0	0	1	1	1	1	1	0	1	1	1	10	2	2	2	3
2	26	1	NiTi	44	RH	1	1	0	0	1	1	1	0	1	1	1	1	1	10	2	2	1	4
2	32	1	NiTi	30	BM	1	1	1	1	1	1	0	1	1	1	0	1	1	11	3	3	2	3
2	32	1	NiTi	30	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	32	1	NiTi	30	RH	1	1	1	1	1	1	0	1	0	1	0	1	1	10	3	3	1	3
2	37	1	NiTi	7	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	37	1	NiTi	7	GW	1	0	0	1	1	0	0	1	0	1	1	1	1	8	1	2	1	4
2	37	1	NiTi	7	RH	1	0	0	1	1	0	0	1	0	1	1	1	1	8	1	2	1	4
2	41	1	NiTi	83	BM	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	41	1	NiTi	83	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	41	1	NiTi	83	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	46	1	NiTi	55	BM	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	46	1	NiTi	55	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	46	1	NiTi	55	RH	1	1	1	1	1	1	1	1	0	1	1	1	1	12	3	3	1	4
2	52	1	NiTi	45	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	52	1	NiTi	45	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	52	1	NiTi	45	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	58	1	NiTi	77	BM	1	1	0	1	1	0	0	1	0	1	1	1	1	9	2	2	1	4
2	58	1	NiTi	77	GW	1	0	1	1	1	1	0	1	1	1	1	1	1	11	2	3	2	4
2	58	1	NiTi	77	RH	1	1	1	1	1	1	0	1	0	1	0	1	1	10	3	3	1	3
2	69	1	NiTi	2	BM	1	1	1	1	1	0	0	0	0	1	1	1	0	8	3	2	0	3
2	69	1	NiTi	2	GW	1	1	1	1	1	1	0	0	1	1	0	1	1	10	3	3	1	3
2	69	1	NiTi	2	RH	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	75	1	NiTi	19	BM	0	0	0	0	1	0	0	0	0	1	1	1	1	5	0	1	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	75	1	NiTi	19	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	75	1	NiTi	19	RH	0	0	1	1	1	1	1	1	0	1	1	1	1	10	1	3	1	4
2	85	1	NiTi	81	BM	1	1	1	1	0	0	2	0	0	1	1	1	1	10	3	1	0	4
2	85	1	NiTi	81	GW	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	85	1	NiTi	81	RH	1	1	1	1	0	1	2	0	0	1	1	0	1	10	3	2	0	3
2	90	1	NiTi	52	BM	1	1	1	1	1	0	2	1	1	1	1	1	1	13	3	2	2	4
2	90	1	NiTi	52	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	90	1	NiTi	52	RH	1	1	1	1	1	1	0	0	0	1	1	0	1	9	3	3	0	3
2	102	1	NiTi	37	BM	1	1	1	1	1	1	0	1	0	1	1	1	1	11	3	3	1	4
2	102	1	NiTi	37	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	102	1	NiTi	37	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	107	1	NiTi	84	BM	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
2	107	1	NiTi	84	GW	1	1	0	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
2	107	1	NiTi	84	RH	0	1	0	1	1	1	2	1	0	1	1	1	1	11	1	3	1	4
2	112	1	NiTi	47	BM	1	1	1	1	1	0	0	1	1	1	1	1	1	11	3	2	2	4
2	112	1	NiTi	47	GW	0	0	1	1	1	1	0	1	1	1	1	1	1	10	1	3	2	4
2	112	1	NiTi	47	RH	0	0	1	1	1	1	2	0	0	1	1	1	1	10	1	3	0	4
2	116	1	NiTi	27	BM	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	116	1	NiTi	27	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	116	1	NiTi	27	RH	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	120	1	NiTi	31	BM	0	1	0	0	1	0	2	1	1	1	1	1	1	10	1	1	2	4
2	120	1	NiTi	31	GW	1	1	0	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
2	120	1	NiTi	31	RH	0	1	0	0	1	0	1	0	0	1	0	1	1	6	1	1	0	3
2	130	1	NiTi	73	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	130	1	NiTi	73	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	130	1	NiTi	73	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	138	1	NiTi	92	BM	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	138	1	NiTi	92	GW	0	1	0	1	1	0	2	0	0	0	1	1	1	8	1	2	0	3
2	138	1	NiTi	92	RH	0	1	0	1	1	1	2	1	1	1	1	1	1	12	1	3	2	4
2	142	1	NiTi	23	BM	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	142	1	NiTi	23	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	142	1	NiTi	23	RH	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	147	1	NiTi	71	BM	0	1	1	1	1	1	2	1	1	0	1	1	1	12	2	3	2	3
2	147	1	NiTi	71	GW	1	1	0	1	1	1	2	1	1	1	1	1	1	13	2	3	2	4
2	147	1	NiTi	71	RH	1	1	0	1	1	1	2	0	0	1	1	1	1	11	2	3	0	4
2	152	1	NiTi	4	BM	0	1	0	0	1	1	2	1	0	1	1	1	1	10	1	2	1	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	152	1	NiTi	4	GW	0	1	0	1	1	1	2	1	0	1	1	1	1	11	1	3	1	4
2	152	1	NiTi	4	RH	0	1	0	1	1	1	2	1	1	1	1	1	1	12	1	3	2	4
2	158	1	NiTi	15	BM	0	1	0	0	1	0	0	0	0	1	1	1	1	6	1	1	0	4
2	158	1	NiTi	15	GW	0	1	1	1	1	1	0	1	0	1	1	1	1	10	2	3	1	4
2	158	1	NiTi	15	RH	0	1	1	1	1	1	0	0	0	0	0	1	1	7	2	3	0	2
2	1	2	Er:YAG	20	BM	0	0	0	0	0	0	0	0	0	1	1	1	0	3	0	0	0	3
2	1	2	Er:YAG	20	GW	0	0	0	0	0	0	2	0	0	0	1	1	0	4	0	0	0	2
2	1	2	Er:YAG	20	RH	1	0	0	0	0	1	2	0	0	1	0	0	0	5	1	1	0	1
2	6	2	Er:YAG	54	BM	0	0	0	0	0	0	2	0	0	1	1	1	0	5	0	0	0	3
2	6	2	Er:YAG	54	GW	0	0	0	0	0	0	1	0	0	0	1	0	1	3	0	0	0	2
2	6	2	Er:YAG	54	RH	0	0	1	0	0	0	1	0	0	1	1	0	1	5	1	0	0	3
2	12	2	Er:YAG	72	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	12	2	Er:YAG	72	GW	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	12	2	Er:YAG	72	RH	1	1	1	0	0	0	1	0	0	1	1	1	1	8	3	0	0	4
2	20	2	Er:YAG	85	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	20	2	Er:YAG	85	GW	1	0	0	0	0	0	2	1	0	1	1	1	1	8	1	0	1	4
2	20	2	Er:YAG	85	RH	1	0	1	0	0	0	2	0	0	1	1	1	1	8	2	0	0	4
2	28	2	Er:YAG	16	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	28	2	Er:YAG	16	GW	0	1	0	1	0	0	2	0	0	1	1	1	1	8	1	1	0	4
2	28	2	Er:YAG	16	RH	1	1	0	0	1	0	2	0	0	1	1	1	1	9	2	1	0	4
2	34	2	Er:YAG	95	BM	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
2	34	2	Er:YAG	95	GW	0	0	0	0	1	1	0	1	0	1	1	1	1	7	0	2	1	4
2	34	2	Er:YAG	95	RH	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	38	2	Er:YAG	39	BM	0	0	0	0	0	0	2	0	0	0	1	1	0	4	0	0	0	2
2	38	2	Er:YAG	39	GW	0	1	0	0	0	0	2	1	0	0	1	1	0	6	1	0	1	2
2	38	2	Er:YAG	39	RH	1	1	1	0	0	0	2	0	0	0	1	0	1	7	3	0	0	2
2	42	2	Er:YAG	29	BM	0	0	0	0	0	1	2	0	0	1	1	1	1	7	0	1	0	4
2	42	2	Er:YAG	29	GW	0	0	0	0	0	1	2	0	1	1	1	1	1	8	0	1	1	4
2	42	2	Er:YAG	29	RH	1	0	1	0	1	1	2	1	1	1	1	1	1	12	2	2	2	4
2	47	2	Er:YAG	40	BM	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	47	2	Er:YAG	40	GW	0	0	1	0	0	0	2	1	0	1	1	0	1	7	1	0	1	3
2	47	2	Er:YAG	40	RH	1	1	1	0	0	0	2	0	0	1	1	0	1	8	3	0	0	3
2	54	2	Er:YAG	21	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	54	2	Er:YAG	21	GW	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
2	54	2	Er:YAG	21	RH	0	1	1	0	0	1	0	0	0	1	0	1	1	6	2	1	0	3
2	59	2	Er:YAG	79	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	59	2	Er:YAG	79	GW	0	0	1	0	0	0	1	0	0	1	0	1	1	5	1	0	0	3
2	59	2	Er:YAG	79	RH	0	0	1	0	0	0	1	0	0	1	1	0	1	5	1	0	0	3
2	76	2	Er:YAG	13	BM	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	76	2	Er:YAG	13	GW	0	0	0	0	0	0	1	0	0	1	0	0	1	3	0	0	0	2
2	76	2	Er:YAG	13	RH	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	86	2	Er:YAG	17	BM	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
2	86	2	Er:YAG	17	GW	0	0	0	0	0	0	1	0	0	0	0	0	1	2	0	0	0	1
2	86	2	Er:YAG	17	RH	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	91	2	Er:YAG	96	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	91	2	Er:YAG	96	GW	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
2	91	2	Er:YAG	96	RH	0	0	0	0	1	0	2	0	1	1	1	1	1	8	0	1	1	4
2	103	2	Er:YAG	93	BM	1	0	0	0	0	0	2	0	0	1	1	1	1	7	1	0	0	4
2	103	2	Er:YAG	93	GW	1	0	1	0		1	2	1	1	1	1	1	1	11	2	1	2	4
2	103	2	Er:YAG	93	RH	1	0	0	0	0	0	1	1	0	1	1	1	1	7	1	0	1	4
2	108	2	Er:YAG	91	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	108	2	Er:YAG	91	GW	0	0	1	1	1	0	1	1	1	2	1	1	1	11	1	2	2	5
2	108	2	Er:YAG	91	RH	0	0	0	1	1	0	2	0	0	1	1	0	1	7	0	2	0	3
2	113	2	Er:YAG	53	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	113	2	Er:YAG	53	GW	0	0	0	0	0	0	2	1	1	1	1	1	1	8	0	0	2	4
2	113	2	Er:YAG	53	RH	0	0	1	0	0	0	2	0	0	1	1	1	1	7	1	0	0	4
2	117	2	Er:YAG	12	BM	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
2	117	2	Er:YAG	12	GW	0	0	0	0	0	0	1	0	0	0	0	0	1	2	0	0	0	1
2	117	2	Er:YAG	12	RH	1	1	1	0	0	1	2	0	0	1	1	0	1	9	3	1	0	3
2	123	2	Er:YAG	18	BM	0	0	0	0	0	0	2	0	0	0	1	1	1	5	0	0	0	3
2	123	2	Er:YAG	18	GW	0	1	1	0	0	0	1	0	0	0	0	1	1	5	2	0	0	2
2	123	2	Er:YAG	18	RH	0	1	1	0	0	1	2	0	0	1	1	0	1	8	2	1	0	3
2	132	2	Er:YAG	6	BM	0	0	0	0	0	0	2	0	0	1	1	0	1	5	0	0	0	3
2	132	2	Er:YAG	6	GW	0	0	0	0	0	0	1	1	0	0	0	1	1	4	0	0	1	2
2	132	2	Er:YAG	6	RH	1	0	0	0	0	0	1	1	0	1	0	1	1	6	1	0	1	3
2	139	2	Er:YAG	8	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	139	2	Er:YAG	8	GW	0	0	1	0	0	1	0	0	0	1	1	1	1	6	1	1	0	4
2	139	2	Er:YAG	8	RH	1	0	0	0	1	1	0	0	0	1	1	1	1	7	1	2	0	4
2	143	2	Er:YAG	5	BM	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
2	143	2	Er:YAG	5	GW	0	0	0	0	0	0	1	0	0	1	0	1	1	4	0	0	0	3
2	143	2	Er:YAG	5	RH	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	148	2	Er:YAG	26	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	148	2	Er:YAG	26	GW	1	1	1	0	0	0	1	0	0	1	1	0	1	7	3	0	0	3
2	148	2	Er:YAG	26	RH	1	1	1	0	0	0	2	0	1	1	1	1	1	10	3	0	1	4
2	153	2	Er:YAG	10	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	153	2	Er:YAG	10	GW	0	0	0	0	0	0	2	1	0	1	1	1	1	7	0	0	1	4
2	153	2	Er:YAG	10	RH	1	0	0	0	0	0	2	0	0	1	1	1	1	7	1	0	0	4
2	159	2	Er:YAG	62	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	159	2	Er:YAG	62	GW	0	0	0	0	0	0	1	1	1	1	1	0	1	6	0	0	2	3
2	159	2	Er:YAG	62	RH	0	1	0	0	0	1	1	0	0	1	1	0	1	6	1	1	0	3
2	3	3	Er,Cr:YSGG	28	BM	0	1	1	0	0	0	2	0	0	1	1	1	1	8	2	0	0	4
2	3	3	Er,Cr:YSGG	28	GW	0	1	1	0	1	1	2	1	0	1	1	0	1	10	2	2	1	3
2	3	3	Er,Cr:YSGG	28	RH	0	1	1	0	0	0	2	0	0	1	0	0	1	6	2	0	0	2
2	13	3	Er,Cr:YSGG	66	BM	1	1	0	1	0	0	2	0	0	1	1	1	1	9	2	1	0	4
2	13	3	Er,Cr:YSGG	66	GW	1	0	0	0	0	1	2	1	1	1	1	1	1	10	1	1	2	4
2	13	3	Er,Cr:YSGG	66	RH	1	1	1	0	0	0	2	0	0	1	1	0	1	8	3	0	0	3
2	21	3	Er,Cr:YSGG	67	BM	0	0	1	0	1	0	1	0	0	1	1	1	1	7	1	1	0	4
2	21	3	Er,Cr:YSGG	67	GW	1	1	1	0	0	1	0	1	0	1	1	1	1	9	3	1	1	4
2	21	3	Er,Cr:YSGG	67	RH	1	1	1	0	1	1	0	1	0	0	0	1	1	8	3	2	1	2
2	29	3	Er,Cr:YSGG	43	BM	0	0	0	0	0	0	2	0	1	1	1	0		5	0	0	1	2

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	29	3	Er,Cr:YSGG	43	GW	1	1	1	0	0	1	2	1	1	0	1	1	1	11	3	1	2	3
2	29	3	Er,Cr:YSGG	43	RH	1	1		0	0		2	0	0	1	0	0	1	6	2	0	0	2
2	35	3	Er,Cr:YSGG	3	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	35	3	Er,Cr:YSGG	3	GW	0	1	1	0	1	1	1	1	1	1	1	1	1	11	2	2	2	4
2	35	3	Er,Cr:YSGG	3	RH	0	1	1	0	0	1	2	1	1	1	1	1	1	11	2	1	2	4
2	39	3	Er,Cr:YSGG	32	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	39	3	Er,Cr:YSGG	32	GW	0	0	0	0	0	0	1	0	0	1	1	0	1	4	0	0	0	3
2	39	3	Er,Cr:YSGG	32	RH	0	1	1	0	0	0	2	0	0	1	0	1	1	7	2	0	0	3
2	44	3	Er,Cr:YSGG	48	BM	0	0	1	0	0	1	2	1	1	1	1	1	1	10	1	1	2	4
2	44	3	Er,Cr:YSGG	48	GW	0	0	1	0	1	1	1	1	0	1	0	1	1	8	1	2	1	3
2	44	3	Er,Cr:YSGG	48	RH	1	1	1	0	0	1	2	0	0	1	0	1	1	9	3	1	0	3
2	56	3	Er,Cr:YSGG	76	BM	0	0	1	0	1	0	2	0	0	1	1	1	1	8	1	1	0	4
2	56	3	Er,Cr:YSGG	76	GW	0	0	1	0	0	1	2	1	1	1	1	1	1	10	1	1	2	4
2	56	3	Er,Cr:YSGG	76	RH	0	0	1	0	0	0	0	0	0	0	1	1	1	4	1	0	0	3
2	60	3	Er,Cr:YSGG	38	BM	1	1	0	1	1	0	2	0	0	1	1	1	1	10	2	2	0	4
2	60	3	Er,Cr:YSGG	38	GW	1	1	1	0	1	1	1	1	1	1	1	1	1	12	3	2	2	4
2	60	3	Er,Cr:YSGG	38	RH	1	1	1	0	1	0	2	0	0	0	0	1	1	8	3	1	0	2
2	72	3	Er,Cr:YSGG	57	BM	1	1	1	1	1	1	1	0	0	1	1	1	1	11	3	3	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	72	3	Er,Cr:YSGG	57	GW	0	1	1	1	1	1	0	1	1	1	1	1	1	11	2	3	2	4
2	72	3	Er,Cr:YSGG	57	RH	0	1	1	0	1	1	0	1	0	1	1	1	1	9	2	2	1	4
2	87	3	Er,Cr:YSGG	70	BM	0	1	1	0	1	0	2	0	0	1	1	1	1	9	2	1	0	4
2	87	3	Er,Cr:YSGG	70	GW	1	1	1	0	1	1	1	1	1	1	1	1	1	12	3	2	2	4
2	87	3	Er,Cr:YSGG	70	RH	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
2	92	3	Er,Cr:YSGG	1	BM	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
2	92	3	Er,Cr:YSGG	1	GW	0	1	0	0	1	0	0	1	0	1	1	1	1	7	1	1	1	4
2	92	3	Er,Cr:YSGG	1	RH	0	1	1	0	0	1	1	0	0	1	1	1	1	8	2	1	0	4
2	104	3	Er,Cr:YSGG	14	BM	0	0	1	0	0	0	1	0	0	1	1	1	1	6	1	0	0	4
2	104	3	Er,Cr:YSGG	14	GW	1	1	1	0	1	1	1	1	0	1	1	1	1	11	3	2	1	4
2	104	3	Er,Cr:YSGG	14	RH	1	1	1	0	0	1	0	0	0	0	1	1	1	7	3	1	0	3
2	109	3	Er,Cr:YSGG	49	BM	0	0	1	1	1	0	2	0	0	1	1	1	1	9	1	2	0	4
2	109	3	Er,Cr:YSGG	49	GW	0	1	1	0	1	1	2	1	0	1	1	1	1	11	2	2	1	4
2	109	3	Er,Cr:YSGG	49	RH	1	1	1	0	1	1	2	1	0	1	1	1	1	12	3	2	1	4
2	114	3	Er,Cr:YSGG	74	BM	1	1	1	1	1	1	2	0	0	1	1	1	1	12	3	3	0	4
2	114	3	Er,Cr:YSGG	74	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	114	3	Er,Cr:YSGG	74	RH	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	118	3	Er,Cr:YSGG	69	BM	0	0	0	0	0	1	2	0	0	1	1	1	1	7	0	1	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	118	3	Er,Cr:YSGG	69	GW	0	0	0	0	1	1	1	1	1	1	1	1	1	9	0	2	2	4
2	118	3	Er,Cr:YSGG	69	RH	0	0	1	0	1	0	1	1	0	1	1	1	1	8	1	1	1	4
2	126	3	Er,Cr:YSGG	46	BM	0	0	1	0	0	0	0	0	0	1	1	1	1	5	1	0	0	4
2	126	3	Er,Cr:YSGG	46	GW	0	1	1	0	0	0	0	1	0	1	1	1	1	7	2	0	1	4
2	126	3	Er,Cr:YSGG	46	RH	1	0	0	0	0	0	0	0	0	1	1	0	1	4	1	0	0	3
2	134	3	Er,Cr:YSGG	41	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	134	3	Er,Cr:YSGG	41	GW	0	0	1	0	0	1	0	1	0	1	1	1	1	7	1	1	1	4
2	134	3	Er,Cr:YSGG	41	RH	0	1	1	0	0	0	2	0	0	1	1	1	1	8	2	0	0	4
2	140	3	Er,Cr:YSGG	68	BM	0	1	0	0	1	0	2	1	1	1	1	1	1	10	1	1	2	4
2	140	3	Er,Cr:YSGG	68	GW	0	1	1	1	1	1	1	1	1	1	1	1	1	12	2	3	2	4
2	140	3	Er,Cr:YSGG	68	RH	1	1	1	0	1	1	1	1	1	1	0	0	1	10	3	2	2	2
2	144	3	Er,Cr:YSGG	11	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	144	3	Er,Cr:YSGG	11	GW	0	0	1	0	0	1	1	0	0	1	1	1	1	7	1	1	0	4
2	144	3	Er,Cr:YSGG	11	RH	0	0	1	0	0	1	2	0	0	1	0	1	1	7	1	1	0	3
2	149	3	Er,Cr:YSGG	22	BM	0	0	1	0	0	1	1	0	0	1	1	1	1	7	1	1	0	4
2	149	3	Er,Cr:YSGG	22	GW	1	1	1	1	1	1	0	0	0	1	0	1	1	9	3	3	0	3
2	149	3	Er,Cr:YSGG	22	RH	0	1	1	1	1	1	1	1	0	1	1	1	1	11	2	3	1	4
2	156	3	Er,Cr:YSGG	25	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	156	3	Er,Cr:YSGG	25	GW	0	0	1	0	0	1	1	1	1	1	1	1	1	9	1	1	2	4
2	156	3	Er,Cr:YSGG	25	RH	0	0	1	0	0	0	2	1	0	1	1	1	1	8	1	0	1	4
2	160	3	Er,Cr:YSGG	82	BM	1	1	1	0	0	1	1	0	0	1	1	1	1	9	3	1	0	4
2	160	3	Er,Cr:YSGG	82	GW	1	1	1	1	1	1	1	1	1	1	1	1	1	13	3	3	2	4
2	160	3	Er,Cr:YSGG	82	RH	1	1	1	1	1	1	1	1	0	1	0	0	0	9	3	3	1	1
2	4	4	Unpreppared	56	BM	0	0	0	0	0	0	2	0	1	1	1	1	1	7	0	0	1	4
2	4	4	Unpreppared	56	GW	0	1	0	0	0	0	1	0	0	1	0	0	1	4	1	0	0	2
2	4	4	Unpreppared	56	RH	1	1	0	0	0	1	1	0	0	1	1	1	1	8	2	1	0	4
2	9	4	Unpreppared	75	BM	1	1	1	0	0	0	2	0	1	1	1	1	1	10	3	0	1	4
2	9	4	Unpreppared	75	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	9	4	Unpreppared	75	RH	1	1	1	0	0	0	1	0	0	1	1	1	1	8	3	0	0	4
2	15	4	Unpreppared	58	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	15	4	Unpreppared	58	GW	0	0	0	0	0	0	0	1	1	1	1	1	1	6	0	0	2	4
2	15	4	Unpreppared	58	RH	0	0	1	0	1	1	0	1	0	0	1	1	1	7	1	2	1	3
2	22	4	Unpreppared	33	BM	1	1	1	0	0	1	0	1	1	1	1	1	1	10	3	1	2	4
2	22	4	Unpreppared	33	GW	0	1	1	0	0	1	0	0	1	1	1	1	1	8	2	1	1	4
2	22	4	Unpreppared	33	RH	0	0	1	0	0	1	1	0	1	1	1	1	1	8	1	1	1	4
2	30	4	Unpreppared	80	BM	1	1	0	1	1	0	2	0	0	1	1	1	1	10	2	2	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	30	4	Unpreppared	80	GW	1	1	0	1	1	1	0	1	0	1	1	1	1	10	2	3	1	4
2	30	4	Unpreppared	80	RH	1	1	0	1	1	1	2	0	0	1	0	0	1	9	2	3	0	2
2	36	4	Unpreppared	24	BM	1	0	0	1	0	1	0	1	0	1	1	1	1	8	1	2	1	4
2	36	4	Unpreppared	24	GW	1	1	1	1	1	1	0	1	1	1	1	1	1	12	3	3	2	4
2	36	4	Unpreppared	24	RH	1	1	1	1	0	0	0	1	1	1	1	1	1	10	3	1	2	4
2	40	4	Unpreppared	60	BM	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	40	4	Unpreppared	60	GW	1	0	1	1	1	1	1	1	0	1	1	1	1	11	2	3	1	4
2	40	4	Unpreppared	60	RH	1	0	0	1	1	1	0	1	0	1	1	1	1	9	1	3	1	4
2	50	4	Unpreppared	86	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	50	4	Unpreppared	86	GW	0	1	0	0	0	0	2	1	0	1	1	1	1	8	1	0	1	4
2	50	4	Unpreppared	86	RH	0	1	0	0	0	0	1	0	0	1	1	1	1	6	1	0	0	4
2	57	4	Unpreppared	65	BM	1	1	0	1	1	0	2	0	0	1	1	1	1	10	2	2	0	4
2	57	4	Unpreppared	65	GW	1	1	0	0	1	0	0	1	0	1	1	1	1	8	2	1	1	4
2	57	4	Unpreppared	65	RH	1	1	1	1	1	0	0	0	0	1	1	1	1	9	3	2	0	4
2	65	4	Unpreppared	64	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	65	4	Unpreppared	64	GW	0	0	0	0	0	1	2	1	0	1	1	1	1	8	0	1	1	4
2	65	4	Unpreppared	64	RH	0	0	0	1	1	1	2	1	0	1	1	1	1	10	0	3	1	4
2	74	4	Unpreppared	59	BM	1	1	1	1	1	0	2	0	0	1	1	1	1	11	3	2	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	74	4	Unpreppared	59	GW	1	1	0	1	1	1	0	1	1	1	1		1	10	2	3	2	3
2	74	4	Unpreppared	59	RH	1	1	0	1	0	0	0	1	0	1	1	1	1	8	2	1	1	4
2	83	4	Unpreppared	94	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	83	4	Unpreppared	94	GW	0	0	0	0	1	0	2	1	0	1	1	1	1	8	0	1	1	4
2	83	4	Unpreppared	94	RH	0	0	0	0	1	1	0	0	0	1	1	0	1	5	0	2	0	3
2	89	4	Unpreppared	51	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	89	4	Unpreppared	51	GW	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
2	89	4	Unpreppared	51	RH	0	0	0	0	0	1	0	0	0	1	1	1	1	5	0	1	0	4
2	97	4	Unpreppared	9	BM	0	0	0	0	0	0	1	0	0	1	1	1	1	5	0	0	0	4
2	97	4	Unpreppared	9	GW	0	0	1	0	1	1	1	0	0	1	1	1	1	8	1	2	0	4
2	97	4	Unpreppared	9	RH	0	0	1	0	1	1	1	0	0	1	1	1	1	8	1	2	0	4
2	106	4	Unpreppared	87	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4
2	106	4	Unpreppared	87	GW	0	0	0	0	0	0	1	1	1	1	1	1	1	7	0	0	2	4
2	106	4	Unpreppared	87	RH	0	0	0	0	0	1	1	0	0	1	1	0	1	5	0	1	0	3
2	110	4	Unpreppared	61	BM	1	1	1	1	1	1	2	1	0	1	1	1	1	13	3	3	1	4
2	110	4	Unpreppared	61	GW	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	110	4	Unpreppared	61	RH	1	1	1	1	1	1	2	1	1	1	1	1	1	14	3	3	2	4
2	115	4	Unpreppared	89	BM	0	0	1	0	0	0	1	1	0	1	1	1	1	7	1	0	1	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	115	4	Unpreppared	89	GW	0	1	1	0	1	1	1	1	0	1	1	1	1	10	2	2	1	4
2	115	4	Unpreppared	89	RH	0	0	1	0	0	1	1	1	0	1	1	1	1	8	1	1	1	4
2	119	4	Unpreppared	50	BM	0	0	0	0	1	1	0	0	0	1	1	1	0	5	0	2	0	3
2	119	4	Unpreppared	50	GW	0	0	0	0	0	0	1	1	1	1	1	1	1	7	0	0	2	4
2	119	4	Unpreppared	50	RH	1	1	1	1	1	0	0	0	0	1	0	1	1	8	3	2	0	3
2	128	4	Unpreppared	88	BM	1	0	0	1	0	0	2	1	1	1	1	1	1	10	1	1	2	4
2	128	4	Unpreppared	88	GW	0	0	0	1	1	1	2	1	1	1	1	1	1	11	0	3	2	4
2	128	4	Unpreppared	88	RH	1	0	1	1	1	0	2	1	1	1	1	1	1	12	2	2	2	4
2	141	4	Unpreppared	90	BM	0	0	0	0	0	0	0	0	0	1	1	1	1	4	0	0	0	4
2	141	4	Unpreppared	90	GW	0	0	0	0	0	0	0	1	0	1	1	1	1	5	0	0	1	4
2	141	4	Unpreppared	90	RH	0	0	0	1	1	1	0	0	0	1	1	1	1	7	0	3	0	4
2	145	4	Unpreppared	35	BM	0	0	0	0	0	1	2	0	0	1	1	1	1	7	0	1	0	4
2	145	4	Unpreppared	35	GW	0	0	0	0	0	1	2	1	0	1	1	1	1	8	0	1	1	4
2	145	4	Unpreppared	35	RH	1	1	0	0	0	1	2	1	0	1	1	1	1	10	2	1	1	4
2	151	4	Unpreppared	42	BM	0	0	1	0	0	0	0	0	0	1	1	1	1	5	1	0	0	4
2	151	4	Unpreppared	42	GW	0	1	1	0	0	1	0	0	0	1	1	1	1	7	2	1	0	4
2	151	4	Unpreppared	42	RH	1	1	0	0	0	1	0	1	0	1	1	1	1	8	2	1	1	4
2	157	4	Unpreppared	78	BM	0	0	0	0	0	0	2	0	0	1	1	1	1	6	0	0	0	4

Experiment	Specimen	Group No.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smoothness coronal1/3	Smoothness mid 1/3	Smoothness apical 1/3	Apical stop	Flow	Taper	Apical zip	Elbows	Ledges	Perforations	Overall total	Debris total	Smoothness total	Form total	Aberrations total
2	157	4	Unpreppared	78	GW	0	1	0	0	1	1	1	1	1	1	1	1	1	10	1	2	2	4
2	157	4	Unpreppared	78	RH	0	0	0	1	1	1	1	0	0	1	1	1	1	8	0	3	0	4

Appendix 9 Study 1 statistical analysis

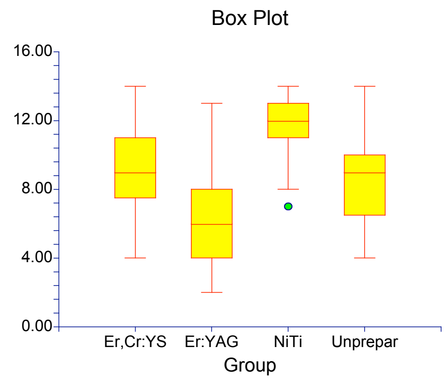
Statistical analysis for Experiment 1

Overall score Analysis of variance report

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	0.5894	0.555616	Accept
Kurtosis Normality of Residuals	-1.4077	0.159226	Accept
Omnibus Normality of Residuals	2.3289	0.312092	Accept
Modified-Levene Equal-Variance Test	5.6106	0.000947	Reject

Box Plot Section



Kruskal-Wallis One-Way ANOVA on Ranks

Hypotheses

Ho: All medians are equal.

Ha: At least two medians are different.

Test Results

Method	DF	Chi-Square (H)	Prob Level	Decision(0.05)
Not Corrected for Ties	3	121.307	0.000000	Reject Ho
Corrected for Ties	3	122.4544	0.000000	Reject Ho

Number Sets of Ties 12

Multiplicity Factor 223830

Group Detail

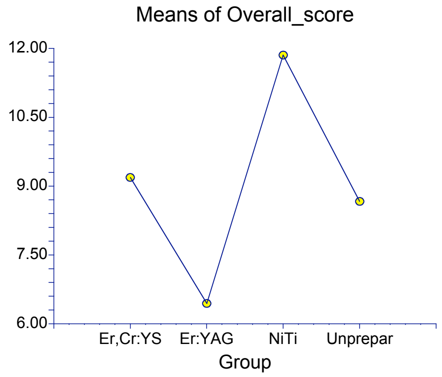
Group	Count	Sum of Ranks	Mean Rank	Z-Value	Median
Er,Cr:YSGG	69	10052.50	145.69	0.1359	9

Er:YAG	75	5718.00	76.24	-8.2537	6
NiTi	75	16829.00	224.39	9.6595	12
Unprepared	69	9016.50	130.67	-1.5814	9

Means and Effects Section

Term	Count	Mean	Standard Error	Effect
All	288	9.041667		0.1255153
A: Group				
Er,Cr:YSGG	69	9.188406	0.2766469	9.06289
Er:YAG	75	6.44	0.2653504	6.314485
NiTi	75	11.85333	0.2653504	11.72782
Unprepared	69	8.666667	0.2766469	8.541151

Plots of Means Section



Kruskal-Wallis Multiple-Comparison Z-Value Test

Overall_score	Er,Cr:YSGG	Er:YAG	NiTi	Unprepared
Er,Cr:YSGG	0.0000	5.0226	5.6915	1.0639
Er:YAG	5.0226	0.0000	10.9445	3.9367
Unprepared	1.0639	3.9367	6.7774	0.0000

Regular Test: Medians significantly different if z-value > 1.9600

Bonferroni Test: Medians significantly different if z-value > 2.6383

Result

Modified-Levene Equal-Variance Test suggests that the assumption of equal variance is not met therefore Kruskal-wallis may not be valid. However the samples are of equal sizes should nullify this [1]. Alternatively use Mann-Whitney U test and reduce alpha for multiple comparisons.

The median overall score for each of the groups are significantly different ($p<0.05$). The NiTi median overall score is significantly greater than Er,Cr:YSGG, Er:YAG and Unprepared ($p<0.05$). The Er:YAG median overall score is significantly less than NiTi, Er,Cr:YSGG and Unprepared ($p<0.05$). There is no significant difference between the median overall scores of Er,Cr:YSGG and Unprepared ($p>0.05$).

NiTi median overall score > (Er,Cr:YSGG ≈ Unprepared) > Er:YAG

Overall score Two-sample test report

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Variable Overall_score

Er,Cr:YSGG v Er:YAG

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	69	9.188406	2.283414	0.2748908	8.440948	9.935863
Group=Er:YAG	75	6.44	2.692532	0.3109068	5.596666	7.283334

Note: T-alpha (Group=Er,Cr:YSGG) = 2.7191, T-alpha (Group=Er:YAG) = 2.7125

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.6928	0.488411	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.0210	0.307262	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	1.5224	0.467098	Cannot reject normality
Skewness Normality (Group=Er:YAG)	1.6301	0.103090	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.4628	0.143510	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	4.7970	0.090855	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.3904	0.167747	Cannot reject equal variances
Modified-Levene Equal-Variance Test	2.1181	0.147779	Cannot reject equal variances

Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

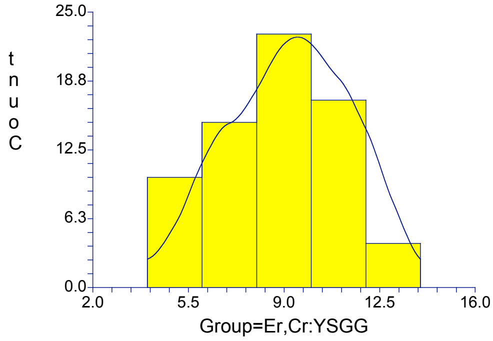
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	4024	6439	5002.5	248.8422
Group=Er:YAG	1151	4001	5437.5	248.8422

Number Sets of Ties = 11, Multiplicity Factor = 29070

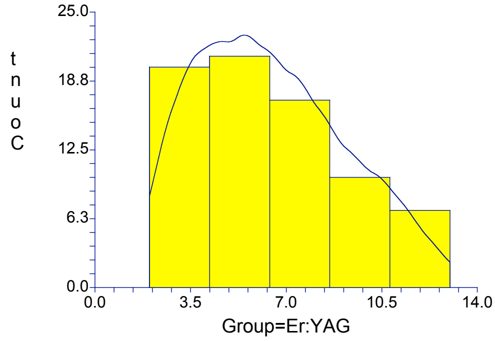
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	5.7727	0.000000	Reject Ho	5.7707	0.000000	Reject Ho
Diff<0	5.7727	1.000000	Accept Ho	5.7747	1.000000	Accept Ho
Diff>0	5.7727	0.000000	Reject Ho	5.7707	0.000000	Reject Ho

Plots Section

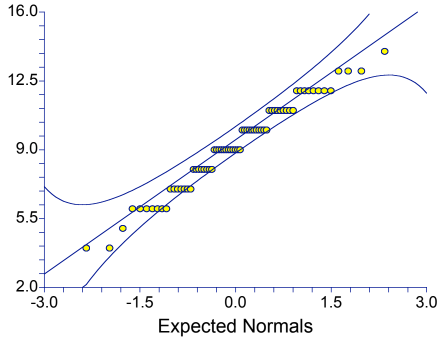
Histogram of Group=Er,Cr:YSGG



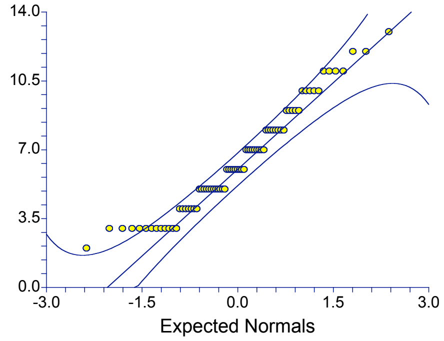
Histogram of Group=Er:YAG



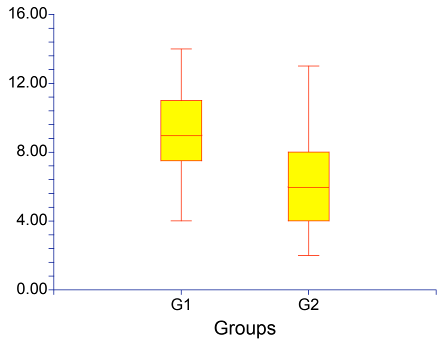
Normal Probability Plot of Group=Er,Cr:YSGG



Normal Probability Plot of Group=Er:YAG



Box Plot



Er,Cr:YSGG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	69	9.188406	2.283414	0.2748908	8.440948	9.935863
Group=NiTi	75	11.85333	1.698118	0.1960817	11.32146	12.3852

Note: T-alpha (Group=Er,Cr:YSGG) = 2.7191, T-alpha (Group=NiTi) = 2.7125

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.6928	0.488411	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.0210	0.307262	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	1.5224	0.467098	Cannot reject normality
Skewness Normality (Group=NiTi)	-2.4847	0.012966	Cannot reject normality
Kurtosis Normality (Group=NiTi)	0.0953	0.924101	Cannot reject normality
Omnibus Normality (Group=NiTi)	6.1829	0.045437	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.8081	0.013643	Cannot reject equal variances
Modified-Levene Equal-Variance Test	7.1820	0.008235	Reject equal variances

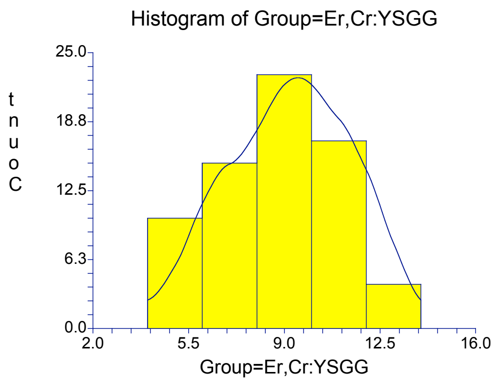
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

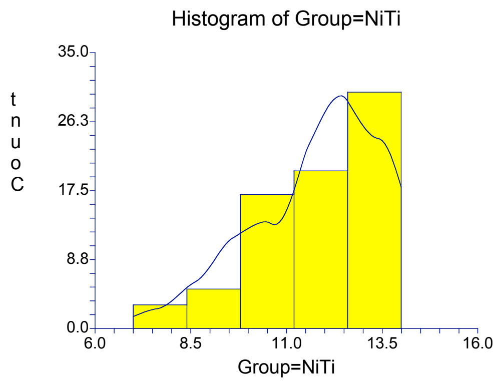
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	921	3336	5002.5	247.8652
Group=NiTi	4254	7104	5437.5	247.8652

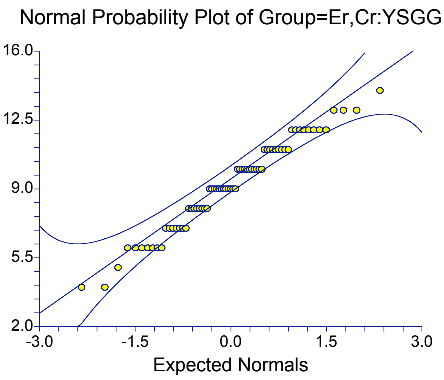
Number Sets of Ties = 10, Multiplicity Factor = 52242

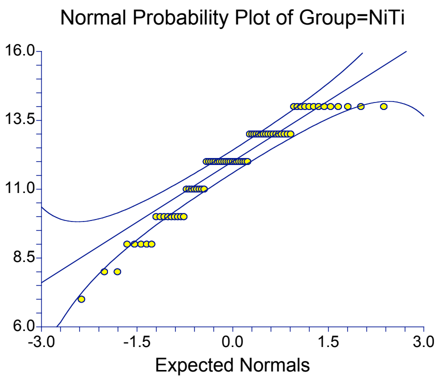
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-6.7234	0.000000	Reject Ho	-6.7214	0.000000	Reject Ho
Diff<0	-6.7234	0.000000	Reject Ho	-6.7214	0.000000	Reject Ho
Diff>0	-6.7234	1.000000	Accept Ho	-6.7254	1.000000	Accept Ho

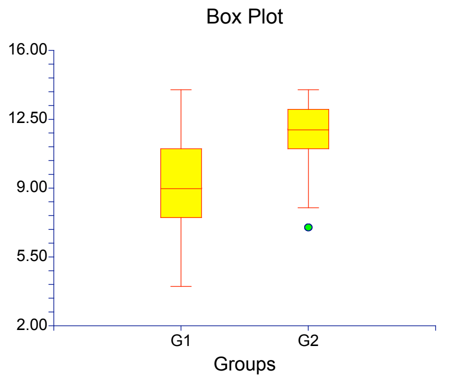
Plots Section











Er,Cr:YSGG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	69	9.188406	2.283414	0.2748908	8.440948	9.935863
Group=Unprepared	69	8.666667	2.411167	0.2902704	7.87739	9.455943

Note: T-alpha (Group=Er,Cr:YSGG) = 2.7191, T-alpha (Group=Unprepared) = 2.7191

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.6928	0.488411	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.0210	0.307262	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	1.5224	0.467098	Cannot reject normality
Skewness Normality (Group=Unprepared)	0.2217	0.824518	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	-1.1231	0.261382	Cannot reject normality
Omnibus Normality (Group=Unprepared)	1.3106	0.519289	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.1150	0.654761	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.1315	0.717489	Cannot reject equal variances

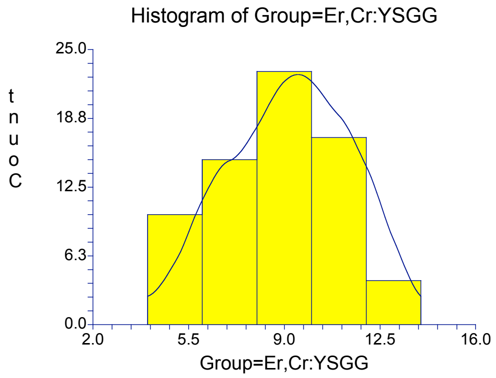
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

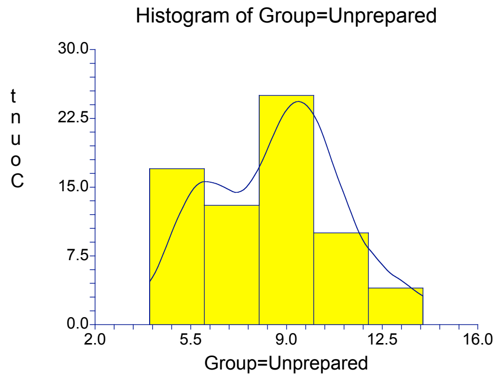
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	2692.5	5107.5	4795.5	232.8722
Group=Unprepared	2068.5	4483.5	4795.5	232.8722

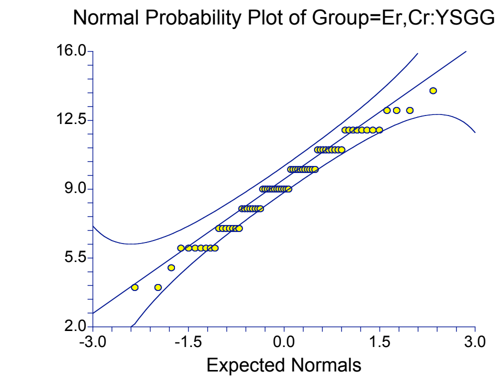
Number Sets of Ties = 11, Multiplicity Factor = 43782

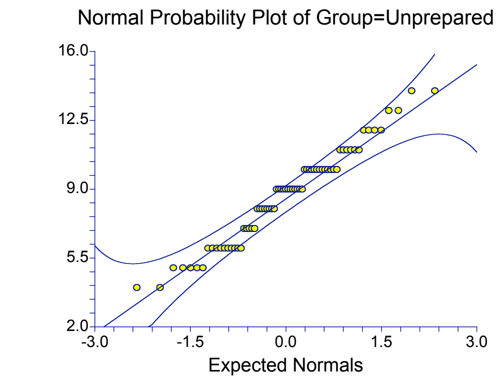
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	1.3398	0.180313	Accept Ho	1.3376	0.181013	Accept Ho
Diff<0	1.3398	0.909843	Accept Ho	1.3419	0.910192	Accept Ho
Diff>0	1.3398	0.090157	Accept Ho	1.3376	0.090506	Accept Ho

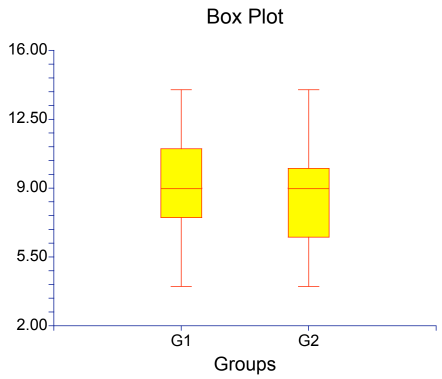
Plots Section











Er,YAG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	75	6.44	2.692532	0.3109068	5.596666	7.283334
Group=NiTi	75	11.85333	1.698118	0.1960817	11.32146	12.3852

Note: T-alpha (Group=Er:YAG) = 2.7125, T-alpha (Group=NiTi) = 2.7125

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	1.6301	0.103090	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.4628	0.143510	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	4.7970	0.090855	Cannot reject normality
Skewness Normality (Group=NiTi)	-2.4847	0.012966	Cannot reject normality
Kurtosis Normality (Group=NiTi)	0.0953	0.924101	Cannot reject normality
Omnibus Normality (Group=NiTi)	6.1829	0.045437	Cannot reject normality
Variance-Ratio Equal-Variance Test	2.5141	0.000102	Reject equal variances
Modified-Levene Equal-Variance Test	16.4381	0.000081	Reject equal variances

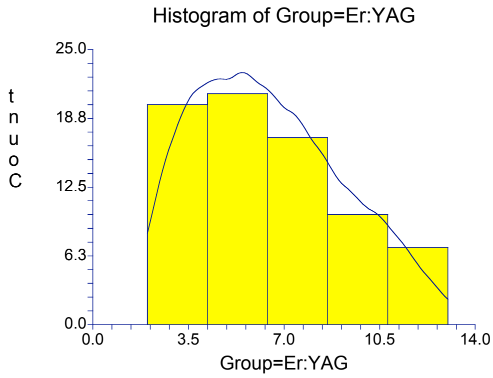
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

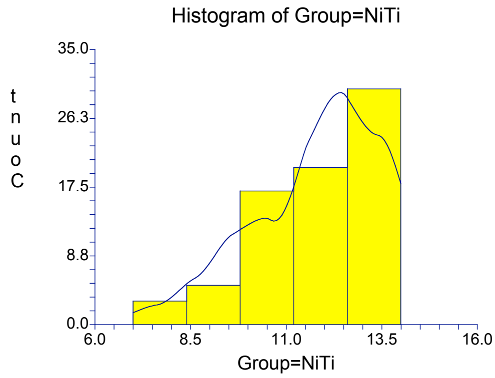
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	318	3168	5662.5	264.8414
Group=NiTi	5307	8157	5662.5	264.8414

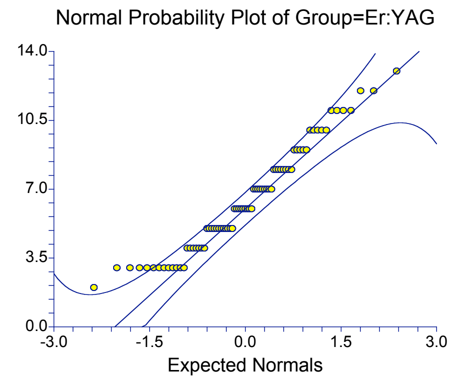
Number Sets of Ties = 12, Multiplicity Factor = 30528

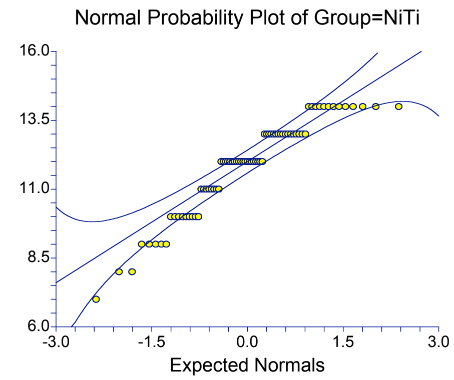
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-9.4188	0.000000	Reject Ho	-9.4170	0.000000	Reject Ho
Diff<0	-9.4188	0.000000	Reject Ho	-9.4170	0.000000	Reject Ho
Diff>0	-9.4188	1.000000	Accept Ho	-9.4207	1.000000	Accept Ho

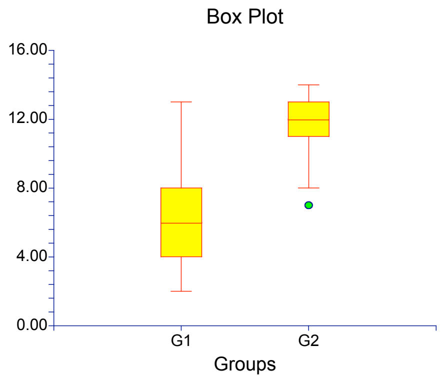
Plots Section











Er:YAG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	75	6.44	2.692532	0.3109068	5.596666	7.283334
Group=Unprepared	69	8.666667	2.411167	0.2902704	7.87739	9.455943

Note: T-alpha (Group=Er:YAG) = 2.7125, T-alpha (Group=Unprepared) = 2.7191

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	1.6301	0.103090	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.4628	0.143510	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	4.7970	0.090855	Cannot reject normality
Skewness Normality (Group=Unprepared)	0.2217	0.824518	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	-1.1231	0.261382	Cannot reject normality
Omnibus Normality (Group=Unprepared)	1.3106	0.519289	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.2470	0.354984	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.1321	0.289137	Cannot reject equal variances

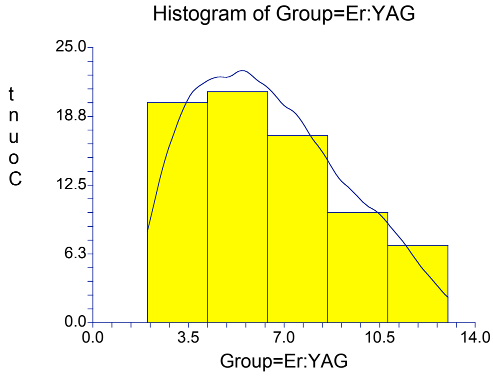
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

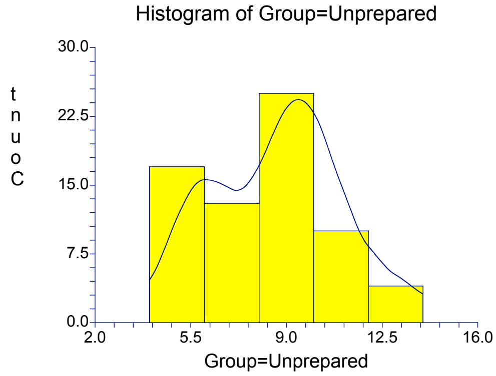
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	1399	4249	5437.5	248.6801
Group=Unprepared	3776	6191	5002.5	248.6801

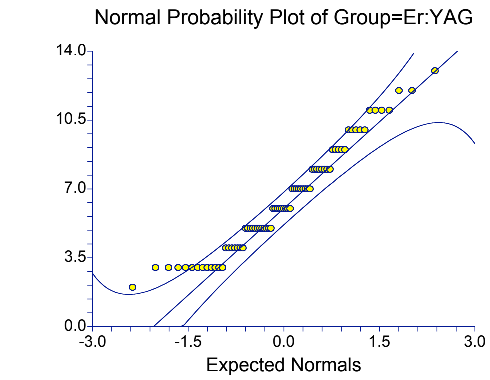
Number Sets of Ties = 12, Multiplicity Factor = 32922

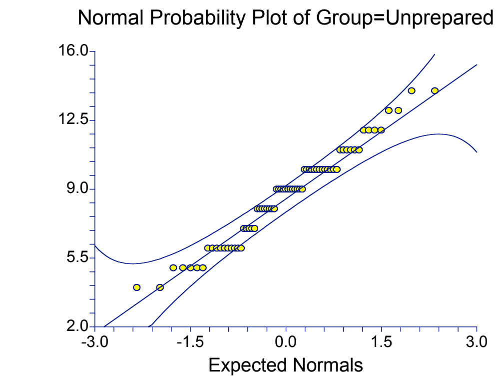
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	4.7792	0.000002	Reject Ho	4.7772	0.000002	Reject Ho
Diff<0	4.7792	0.000001	Reject Ho	4.7772	0.000001	Reject Ho
Diff>0	4.7792	0.999999	Accept Ho	4.7812	0.999999	Accept Ho

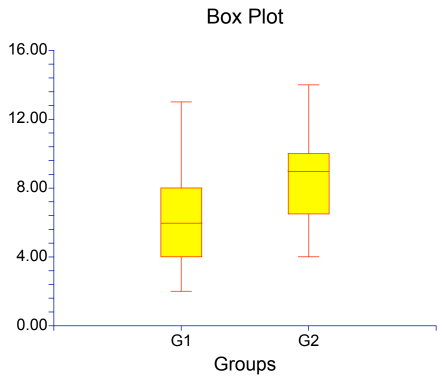
Plots Section











NiTi v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=NiTi	75	11.85333	1.698118	0.1960817	11.32146	12.3852
Group=Unprepared	69	8.666667	2.411167	0.2902704	7.87739	9.455943

Note: T-alpha (Group=NiTi) = 2.7125, T-alpha (Group=Unprepared) = 2.7191

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=NiTi)	-2.4847	0.012966	Cannot reject normality
Kurtosis Normality (Group=NiTi)	0.0953	0.924101	Cannot reject normality
Omnibus Normality (Group=NiTi)	6.1829	0.045437	Cannot reject normality
Skewness Normality (Group=Unprepared)	0.2217	0.824518	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	-1.1231	0.261382	Cannot reject normality
Omnibus Normality (Group=Unprepared)	1.3106	0.519289	Cannot reject normality
Variance-Ratio Equal-Variance Test	2.0161	0.003596	Reject equal variances
Modified-Levene Equal-Variance Test	8.6904	0.003741	Reject equal variances

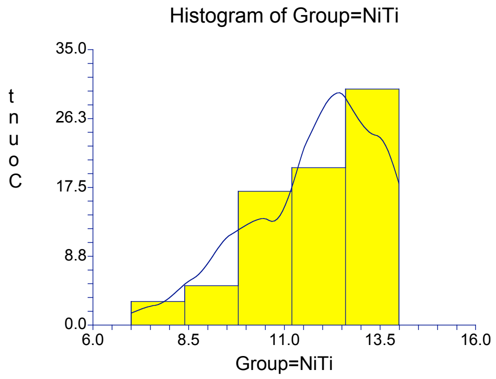
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

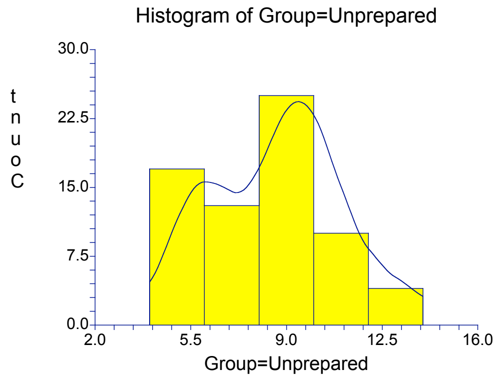
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=NiTi	4418	7268	5437.5	248.1892
Group=Unprepared	757	3172	5002.5	248.1892

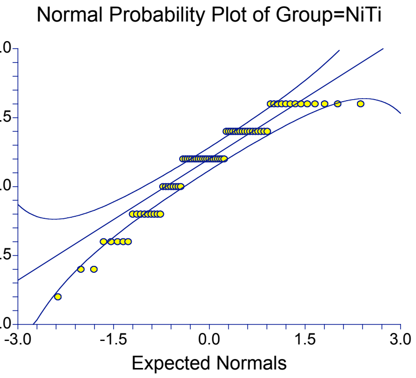
Number Sets of Ties = 11, Multiplicity Factor = 44568

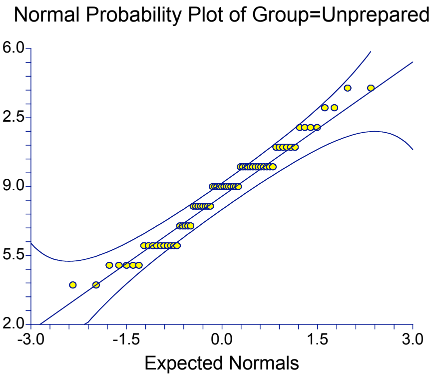
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-7.3754	0.000000	Reject Ho	-7.3734	0.000000	Reject Ho
Diff<0	-7.3754	1.000000	Accept Ho	-7.3774	1.000000	Accept Ho
Diff>0	-7.3754	0.000000	Reject Ho	-7.3734	0.000000	Reject Ho

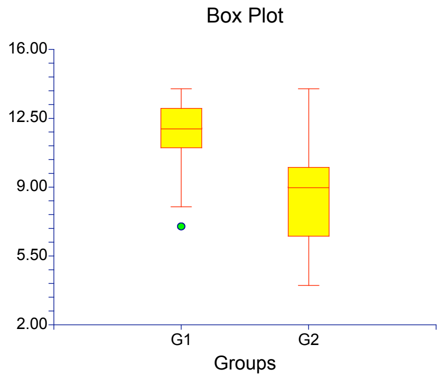
Plots Section











Result

The NiTi median overall score is significantly greater than Er,Cr:YSGG, Er:YAG and Unprepared ($p<0.0083$). The Er:YAG median overall score is significantly less than NiTi, Er,Cr:YSGG and Unprepared ($p<0.0083$). There is no significant difference between the median overall scores of Er,Cr:YSGG and Unprepared ($p>0.0083$).

NiTi median overall score > (Er,Cr:YSGG ≈ Unprepared) > Er:YAG

Criteria Cross tabulation reports

Debris

Combined Report

A debris score of over 2 (i.e. debris score > 2) represents a clinically clean root canal. In other words, a debris score of up to 2 (i.e. debris score ≤ 2) represents more than 5% coverage of debris in 1 or more thirds of the root (E.g. few small conglomerations, many conglomerations, or complete or nearly complete covering).

Counts, Expected, Chi-Square

	Debris		
Group	Up To 2	Over 2	Total
Er,Cr:YSGG	52	17	69
	50.31	18.69	69.00
	0.06	0.15	0.21
Er:YAG	70	5	75
	54.69	20.31	75.00
	4.29	11.54	15.83
NiTi	31	44	75
	54.69	20.31	75.00
	10.26	27.62	37.88
Unprepared	57	12	69
	50.31	18.69	69.00
	0.89	2.39	3.28
Total	210	78	288
	210.00	78.00	288.00
	15.50	41.70	57.20

The number of rows with at least one missing value is 0

Chi-Square Statistics Section

Chi-Square	57.205175	
Degrees of Freedom	3	
Probability Level	0.000000	Reject Ho
Phi	0.445678	
Cramer's V	0.445678	
Pearson's Contingency Coefficient	0.407079	
Tschuprow's T	0.338642	
Lambda A .. Rows dependent	0.183099	
Lambda B .. Columns dependent	0.166667	
Symmetric Lambda	0.178694	
Kendall's tau-B	0.044280	
Kendall's tau-B (with correction for ties)	0.081098	
Kendall's tau-C	0.058835	
Gamma	0.139716	

Smoothness

Combined Report

A smoothness score of over 2 (i.e. smoothness score > 2) represents a clinically smooth and regular root canal preparation. In other words, a smoothness score of up to 2 (i.e. smoothness score ≤ 2) represents more some roughness or irregularity in 1 or more thirds of the root.

Counts, Expected, Chi-Square

	Smoothness		
Group	Up To 2	Over 2	Total
Er,Cr:YSGG	49	20	69
	40.73	28.27	69.00
	1.68	2.42	4.10
Er:YAG	63	12	75
	44.27	30.73	75.00
	7.92	11.42	19.34
NiTi	8	67	75
	44.27	30.73	75.00
	29.72	42.81	72.53
Unprepared	50	19	69
	40.73	28.27	69.00
	2.11	3.04	5.15
Total	170	118	288
	170.00	118.00	288.00
	41.43	59.69	101.12

The number of rows with at least one missing value is 0

Chi-Square Statistics Section

Chi-Square	101.116826	
Degrees of Freedom	3	
Probability Level	0.000000	Reject Ho
Phi	0.592537	
Cramer's V	0.592537	
Pearson's Contingency Coefficient	0.509767	
Tschuprow's T	0.450231	
Lambda A .. Rows dependent	0.258216	
Lambda B .. Columns dependent	0.500000	
Symmetric Lambda	0.344411	
Kendall's tau-B	0.094512	
Kendall's tau-B (with correction for ties)	0.156417	
Kendall's tau-C	0.125579	
Gamma	0.231975	

Apical stop

Combined Report

An apical stop score of over 1 (i.e. apical stop score > 1) represents a clinically well defined apical stop. In other words, an apical stop score of up to 1 (i.e. apical stop score ≤ 1) represents a poorly defined or absent apical stop.

Counts, Expected, Chi-Square

	Apical stop		
Group	Up To 1	Over 1	Total
Er,Cr:YSGG	39	30	69
	39.3	29.7	69.0
	0.00	0.00	0.00
Er:YAG	33	42	75
	42.7	32.3	75.0
	2.21	2.92	5.13
NiTi	45	30	75
	42.7	32.3	75.0
	0.12	0.16	0.28
Unprepared	47	22	69
	39.3	29.7	69.0
	1.51	2.00	3.51
Total	164	124	288
	164.0	124.0	288.0
	3.84	5.08	8.92

The number of rows with at least one missing value is 1

Chi-Square Statistics Section

Chi-Square	8.928562	
Degrees of Freedom	3	
Probability Level	0.030256	Reject Ho
Phi	0.176074	
Cramer's V	0.176074	
Pearson's Contingency Coefficient	0.173406	
Tschuprow's T	0.133787	
Lambda A .. Rows dependent	0.065728	
Lambda B .. Columns dependent	0.072581	
Symmetric Lambda	0.068249	
Kendall's tau-B	-0.064170	
Kendall's tau-B (with correction for ties)	-0.105477	
Kendall's tau-C	-0.085262	
Gamma	-0.172253	

Form

Combined Report

A form score of over 1 (i.e. form score > 1) represents a clinically tapering and flowing root canal preparation. In other words, a form score of up to 1 (i.e. form score ≤ 1) represents more either poor flow and/or taper in the root canal preparation.

Counts, Expected, Chi-Square

	Form		
Group	Up To 1	Over 1	Total
Er,Cr:YSGG	48	21	69
	41.93	27.07	69.00
	0.88	1.36	2.24
Er:YAG	67	8	75
	45.57	29.43	75.00
	10.07	15.60	25.67
NiTi	17	58	75
	45.57	29.43	75.00
	17.91	27.74	45.65
Unprepared	43	26	69
	41.93	27.07	69.00
	0.03	0.04	0.07
Total	175	113	288
	175.00	113.00	288.00
	28.89	44.74	73.63

The number of rows with at least one missing value is 0

Chi-Square Statistics Section

Chi-Square	73.646164	
Degrees of Freedom	3	
Probability Level	0.000000	Reject Ho
Phi	0.505684	
Cramer's V	0.505684	
Pearson's Contingency Coefficient	0.451267	
Tschuprow's T	0.384236	
Lambda A .. Rows dependent	0.234742	
Lambda B .. Columns dependent	0.362832	
Symmetric Lambda	0.279141	
Kendall's tau-B	0.117233	
Kendall's tau-B (with correction for ties)	0.195413	
Kendall's tau-C	0.155768	
Gamma	0.300428	

Aberrations

Combined Report

An aberration score of over 3 (i.e. aberration score > 3) represents a root canal preparation free from any aberration. In other words, an aberration score of up to 3 (i.e. aberration score ≤ 3) represents more a root canal preparation with 1 or more aberrations.

Counts, Expected, Chi-Square

	Aberrations		
Group	Up To 3	Over 3	Total
Er,Cr:YSGG	13	56	69
	17.7	51.3	69.0
	1.26	0.44	1.70
Er:YAG	43	32	75
	19.3	55.7	75.0
	29.22	10.10	39.32
NiTi	11	64	75
	19.3	55.7	75.0
	3.55	1.23	4.78
Unprepared	7	62	69
	17.7	51.3	69.0
	6.49	2.25	8.74
Total	74	214	288
	74.0	214.0	288.0
	40.52	14.02	54.54

The number of rows with at least one missing value is 1

Chi-Square Statistics Section

Chi-Square	54.535827	
Degrees of Freedom	3	
Probability Level	0.000000	Reject Ho
Phi	0.435156	
Cramer's V	0.435156	
Pearson's Contingency Coefficient	0.399014	
Tschuprow's T	0.330647	
Lambda A .. Rows dependent	0.150235	
Lambda B .. Columns dependent	0.148649	
Symmetric Lambda	0.149826	
Kendall's tau-B	0.089866	
Kendall's tau-B (with correction for ties)	0.167393	
Kendall's tau-C	0.119406	
Gamma	0.294902	

Result

The NiTi group was associated with clinically clean, smooth and regular root canal surfaces; that are well flowing and tapered root canal preparations ($p<0.05$).

The experimental Er:YAG group was associated with well defined apical stops in the root canal preparations but were also associated with the formation of aberrations within the root canal preparations ($p<0.05$).

Power analysis (Er,Cr:YSGG vs. Unprepared)

Power analysis (Er,Cr:YSGG vs Unprepared) experiment 1

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.13267	100	100	1.000	0.00830	0.86733	9.2	8.7	2.4	2.4
0.31493	200	200	1.000	0.00830	0.68507	9.2	8.7	2.4	2.4
0.50119	300	300	1.000	0.00830	0.49881	9.2	8.7	2.4	2.4
0.65976	400	400	1.000	0.00830	0.34024	9.2	8.7	2.4	2.4
0.77993	500	500	1.000	0.00830	0.22007	9.2	8.7	2.4	2.4
0.80035	521	521	1.000	0.00830	0.19965	9.2	8.7	2.4	2.4
0.86381	600	600	1.000	0.00830	0.13619	9.2	8.7	2.4	2.4

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 521 and 521 achieve 80% power to detect a difference of 0.5 between the null hypothesis that both group means are 9.2 and the alternative hypothesis that the mean of group 2 is 8.7 with known group standard deviations of 2.4 and 2.4 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Group sample sizes of 100 and 100 achieve 13% power to detect a difference of 0.5 between the null hypothesis that both group means are 9.2 and the alternative hypothesis that the mean of group 2 is 8.7 with known group standard deviations of 2.4 and 2.4 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section

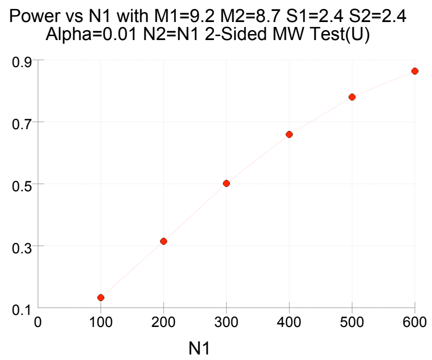


Figure 59 Power analysis, power by sample size

Inter- and intra-evaluator agreement and reliability

Inter-evaluator agreement

Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task. The following guidelines have been proposed for interpreting kappa. [1]

Kappa	Level of agreement
0.93-1.00	Excellent agreement
0.81-0.92	Very good agreement
0.61-0.8	Good agreement
0.41-0.6	Fair agreement
0.21-0.4	Slight agreement
0.01-0.2	Poor agreement
≤0.00	No agreement

Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task. The following Table of Kappa reliability test between evaluators shows fair agreement [1].

Kappa	Evaluator 1 (BM)	Evaluator 2 (GW)	Evaluator 3 (RH)
Evaluator 1 (BM)	1.0	0.503234	0.558669
Evaluator 2 (GW)	0.503234	1.0	0.523316
Evaluator 3 (RH)	0.558669	0.523316	1.0

Cross Tabulation Report experiment 1

Note to calculate kappa a dichotomous data is required and a square table (i.e. 2x2). Thus, the overall score 9 was selected to make the overall score data dichotomous because the mean overall score for the evaluators was close to 9 (mean overall score: BM=8.9, GW=9.1, RH=9.2) and the median overall score for the groups were centred on a score of 9 (median overall score: NiTi=12, Er:YAG=6, Er,Cr:YSGG=9, Unprepared=9).

BM vs. GW

Combined Report

Counts, Expected, Chi-Square

	Overall_BM		
Overall_GW	Up To 9	Over 9	Total
Up To 9	37	8	45
	24.84	20.16	45.00
	5.95	7.33	13.28
Over 9	16	35	51
	28.16	22.84	51.00
	5.25	6.47	11.72
Total	53	43	96
	53.00	43.00	96.00
	11.20	13.80	25.00

The number of rows with at least one missing value is 1

Chi-Square Statistics Section

Chi-Square	24.996887	
Degrees of Freedom	1	
Probability Level	0.000001	Reject Ho
Phi	0.510279	
Cramer's V	0.510279	
Pearson's Contingency Coefficient	0.454523	
Tschuprow's T	0.510279	
Lambda A .. Rows dependent	0.466667	
Lambda B .. Columns dependent	0.441860	
Symmetric Lambda	0.454545	
Kendall's tau-B	0.255921	
Kendall's tau-B (with correction for ties)	0.510279	
Kendall's tau-C	0.506510	
Gamma	0.820098	
Kappa reliability test	0.503234	
Kappa's standard error	0.100653	
Kappa's t value	4.999689	
McNemar's Test Statistic	2.666667	
McNemar's Degrees of Freedom	1	
McNemar's Probability Level	0.102470	

BM vs. RH

Combined Report

Counts, Expected, Chi-Square

	Overall_BM		
Overall_RH	Up To 9	Over 9	Total
Up To 9	42	10	52
	28.71	23.29	52.00
	6.15	7.59	13.74
Over 9	11	33	44
	24.29	19.71	44.00
	7.27	8.96	16.23
Total	53	43	96
	53.00	43.00	96.00
	13.42	16.55	29.97

The number of rows with at least one missing value is 1

Chi-Square Statistics Section

Chi-Square	29.975900	
Degrees of Freedom	1	
Probability Level	0.000000	Reject Ho
Phi	0.558792	
Cramer's V	0.558792	
Pearson's Contingency Coefficient	0.487801	
Tschuprow's T	0.558792	
Lambda A .. Rows dependent	0.522727	
Lambda B .. Columns dependent	0.511628	
Symmetric Lambda	0.517241	
Kendall's tau-B	0.279825	
Kendall's tau-B (with correction for ties)	0.558792	
Kendall's tau-C	0.553819	
Gamma	0.852941	
Kappa reliability test	0.558669	
Kappa's standard error	0.102040	
Kappa's t value	5.475025	
McNemar's Test Statistic	0.047619	
McNemar's Degrees of Freedom	1	
McNemar's Probability Level	0.827259	

GW vs. RH

Combined Report

Counts, Expected, Chi-Square

	Overall_GW		
Overall_RH	Up To 9	Over 9	Total
Up To 9	37	15	52
	24.38	27.63	52.00
	6.54	5.77	12.31
Over 9	8	36	44
	20.63	23.38	44.00
	7.73	6.82	14.55
Total	45	51	96
	45.00	51.00	96.00
	14.27	12.59	26.86

The number of rows with at least one missing value is 1

Chi-Square Statistics Section

Chi-Square	26.855780	
Degrees of Freedom	1	
Probability Level	0.000000	Reject Ho
Phi	0.528912	
Cramer's V	0.528912	
Pearson's Contingency Coefficient	0.467542	
Tschuprow's T	0.528912	
Lambda A .. Rows dependent	0.477273	
Lambda B .. Columns dependent	0.488889	
Symmetric Lambda	0.483146	
Kendall's tau-B	0.265789	
Kendall's tau-B (with correction for ties)	0.528912	
Kendall's tau-C	0.526042	
Gamma	0.834711	
Kappa reliability test	0.523316	
Kappa's standard error	0.100982	
Kappa's t value	5.182256	
McNemar's Test Statistic	2.130435	
McNemar's Degrees of Freedom	1	
McNemar's Probability Level	0.144400	

Intra-evaluator reliability

Spearman rank correlation was calculated to assess intra-evaluator reliability between experiment 1 and experiment 2. The Spearman rank correlation was calculated for overall score (r_s=0.771764) and by convention shows a very good to excellent relationship [1].

The following guidelines have been proposed for interpreting the size of correlations (spearman rank correlation) [1].

r_S	Level of relationship
≥0.75	Very good to excellent relationship
0.5-0.75	Moderate to good relationship
0.25-0.5	Fair degree of relationship
0-0.25	Little or no relationship

Correlation Report

Spearman Correlations Section (Row-Wise Deletion)

Spearman rank correlation between experiment 1 and experiment 2.

Spearman rank correlation (r_s), significance level, sample size

	Apical_stop_1	Overall_score_1	Debris_1	Smoothness_1	Form_1	Aberrations_1
Apical_stop_2	0.616533	0.105999	-0.100936	-0.083702	-0.036343	0.059209
	0.000000	0.072478	0.087292	0.156545	0.539031	0.316673
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000
Overall_score_2	0.114635	0.771764	0.642187	0.653888	0.465691	0.407815
	0.051971	0.000000	0.000000	0.000000	0.000000	0.000000
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000
Debris_2	-0.047216	0.632622	0.760983	0.530784	0.284578	0.213502
	0.424727	0.000000	0.000000	0.000000	0.000001	0.000263
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000
Smoothness_2	-0.058341	0.665528	0.576205	0.667434	0.442115	0.267759
	0.323832	0.000000	0.000000	0.000000	0.000000	0.000004
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000
Form_2	-0.003292	0.528752	0.394719	0.430104	0.444713	0.330776
	0.955636	0.000000	0.000000	0.000000	0.000000	0.000000
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000
Aberrations_2	0.008577	0.293656	0.066299	0.297898	0.210564	0.468504
	0.884771	0.000000	0.262087	0.000000	0.000320	0.000000
	288.000000	288.000000	288.000000	288.000000	288.000000	288.000000

References

1. Dawson B, Trapp RG. Basic & clinical biostatistics. 3rd edn. Boston: Lang Medical Books/McGraw-Hill Medical Publishing Division, 2001.

Appendix 10 Study 2 data

Specimen	Group no.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smear coronal 1/3	Smear mid 1/3	Smear apical 1/3	Overall total	Debris total	Smear total
11	1	NiTi	21	DH	3	3	3	4	4	3	20	9	11
11	1	NiTi	21	ER	3	3	3	4	4	3	20	9	11
11	1	NiTi	21	MS	3	3	3	4	4	3	20	9	11
32	1	NiTi	1	DH	5	5	5	5	5	5	30	15	15
32	1	NiTi	1	ER	5	5	5	5	5	5	30	15	15
32	1	NiTi	1	MS	5	5	5	5	5	5	30	15	15
37	1	NiTi	13	DH	5	4	1	4	4	5	23	10	13
37	1	NiTi	13	ER	5	4	1	5	5	5	25	10	15
37	1	NiTi	13	MS	5	4	1	5	5	5	25	10	15
58	1	NiTi	18	DH	4	4	3	5	5	3	24	11	13
58	1	NiTi	18	ER	4	4	3	5	5	3	24	11	13
58	1	NiTi	18	MS	4	4	3	5	5	3	24	11	13
85	1	NiTi	24	DH	5	5	4	4	4	1	23	14	9
85	1	NiTi	24	ER	5	5	4	4	4	1	23	14	9
85	1	NiTi	24	MS	5	5	4	4	4	1	23	14	9
120	1	NiTi	38	DH	5	5	5	5	4	3	27	15	12
120	1	NiTi	38	ER	5	5	5	5	4	3	27	15	12
120	1	NiTi	38	MS	5	5	5	5	5	3	28	15	13
158	1	NiTi	17	DH	4	5	3	4	4	2	22	12	10
158	1	NiTi	17	ER	5	5	3	4	4	2	23	13	10
158	1	NiTi	17	MS	5	5	3	4	4	2	23	13	10
28	2	Er:YAG	39	DH	3	5	5	4	1	2	20	13	7
28	2	Er:YAG	39	ER	3	5	5	3	1	1	18	13	5
28	2	Er:YAG	39	MS	3	5	5	3	1	1	18	13	5
34	2	Er:YAG	6	DH	5	5	5	5	5	3	28	15	13
34	2	Er:YAG	6	ER	5	5	5	5	5	3	28	15	13
34	2	Er:YAG	6	MS	5	5	5	5	5	3	28	15	13
59	2	Er:YAG	28	DH	5	5	5	4	4	2	25	15	10
59	2	Er:YAG	28	ER	5	5	5	4	4	3	26	15	11
59	2	Er:YAG	28	MS	5	5	5	4	4	2	25	15	10
86	2	Er:YAG	31	DH	5	4	5	4	4	1	23	14	9
86	2	Er:YAG	31	ER	5	4	5	4	4	1	23	14	9
86	2	Er:YAG	31	MS	5	4	5	4	4	1	23	14	9
113	2	Er:YAG	34	DH	5	5	5	3	5	4	27	15	12
113	2	Er:YAG	34	ER	5	5	5	3	5	4	27	15	12
113	2	Er:YAG	34	MS	5	5	5	3	3	4	25	15	10
117	2	Er:YAG	37	DH	3	5	5	3	3	1	20	13	7
117	2	Er:YAG	37	ER	3	5	5	3	3	1	20	13	7
117	2	Er:YAG	37	MS	3	5	5	3	3	1	20	13	7
132	2	Er:YAG	29	DH	4	5	1	4	5	5	24	10	14
132	2	Er:YAG	29	ER	5	5	5	4	5	5	29	15	14
132	2	Er:YAG	29	MS	5	5	5	4	5	5	29	15	14
13	3	Er,Cr:YSGG	23	DH	5	5	5	3	5	2	25	15	10
13	3	Er,Cr:YSGG	23	ER	5	5	5	3	5	2	25	15	10
13	3	Er,Cr:YSGG	23	MS	5	5	5	3	5	2	25	15	10

Specimen	Group no.	Group name	Sequence	Evaluator	Debris coronal 1/3	Debris mid 1/3	Debris apical 1/3	Smear coronal 1/3	Smear mid 1/3	Smear apical 1/3	Overall total	Debris total	Smear total
29	3	Er,Cr:YSGG	9	DH	5	4	3	3	4	3	22	12	10
29	3	Er,Cr:YSGG	9	ER	4	3	3	3	4	3	20	10	10
29	3	Er,Cr:YSGG	9	MS	5	3	3	3	4	3	21	11	10
92	3	Er,Cr:YSGG	36	DH	4	5	4	4	4	2	23	13	10
92	3	Er,Cr:YSGG	36	ER	4	5	4	4	4	1	22	13	9
92	3	Er,Cr:YSGG	36	MS	4	5	4	4	4	1	22	13	9
109	3	Er,Cr:YSGG	11	DH	5	5	5	5	5	2	27	15	12
109	3	Er,Cr:YSGG	11	ER	5	5	5	5	5	2	27	15	12
109	3	Er,Cr:YSGG	11	MS	5	5	5	5	5	2	27	15	12
118	3	Er,Cr:YSGG	40	DH	3	4	4	3	4	2	20	11	9
118	3	Er,Cr:YSGG	40	ER	3	4	4	3	4	2	20	11	9
118	3	Er,Cr:YSGG	40	MS	3	4	4	3	4	2	20	11	9
134	3	Er,Cr:YSGG	26	DH	4	2	5	3	3	1	18	11	7
134	3	Er,Cr:YSGG	26	ER	5	4	4	3	3	1	20	13	7
134	3	Er,Cr:YSGG	26	MS	4	4	4	3	3	1	19	12	7
160	3	Er,Cr:YSGG	8	DH	5	5	3	5	4	2	24	13	11
160	3	Er,Cr:YSGG	8	ER	5	5	3	5	4	2	24	13	11
160	3	Er,Cr:YSGG	8	MS	5	5	3	5	4	2	24	13	11
4	4	Unprepared	33	DH	3	5	5	1	3	3	20	13	7
4	4	Unprepared	33	ER	3	4	5	1	3	3	19	12	7
4	4	Unprepared	33	MS	3	5	5	1	3	3	20	13	7
30	4	Unprepared	3	DH	5	4	2	5	4	5	25	11	14
30	4	Unprepared	3	ER	5	5	2	5	4	5	26	12	14
30	4	Unprepared	3	MS	4	5	2	5	4	5	25	11	14
50	4	Unprepared	27	DH	5	4	4	4	5	1	23	13	10
50	4	Unprepared	27	ER	5	4	4	4	5	1	23	13	10
50	4	Unprepared	27	MS	5	4	4	4	5	1	23	13	10
57	4	Unprepared	19	DH	5	5	1	5	4	1	21	11	10
57	4	Unprepared	19	ER	4	5	1	5	4	1	20	10	10
57	4	Unprepared	19	MS	5	5	1	5	4	1	21	11	10
74	4	Unprepared	14	DH	3	2	3	2	4	2	16	8	8
74	4	Unprepared	14	ER	3	1	3	2	4	2	15	7	8
74	4	Unprepared	14	MS	3	1	3	2	4	2	15	7	8
89	4	Unprepared	15	DH	3	5	4	4	4	2	22	12	10
89	4	Unprepared	15	ER	3	4	3	3	4	2	19	10	9
89	4	Unprepared	15	MS	3	4	4	3	4	2	20	11	9
151	4	Unprepared	7	DH	4	5	5	2	3	3	22	14	8
151	4	Unprepared	7	ER	3	4	5	1	3	3	19	12	7
151	4	Unprepared	7	MS	4	5	5	1	4	3	22	14	8

Appendix 11 Study 2 statistical analysis

Debris Analysis of variance report

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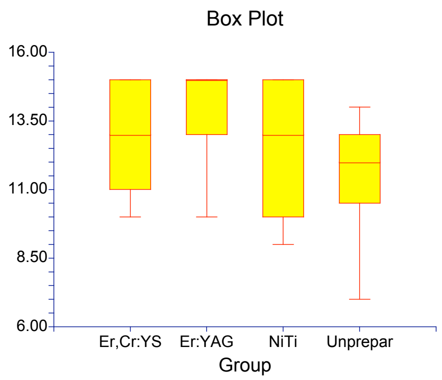
Database

Response Debris_total

Tests of Assumptions Section

	Test	Prob	Decision
Assumption	Value	Level	(0.05)
Skewness Normality of Residuals	-1.8913	0.058583	Accept
Kurtosis Normality of Residuals	-0.8401	0.400841	Accept
Omnibus Normality of Residuals	4.2828	0.117487	Accept
Modified-Levene Equal-Variance Test	2.8909	0.040476	Reject

Box Plot Section



Kruskal-Wallis One-Way ANOVA on Ranks

Hypotheses

Ho: All medians are equal.

Ha: At least two medians are different.

Test Results

Method	DF	Chi-Square (H)	Prob Level	Decision(0.05)
Not Corrected for Ties	3	18.24026	0.000392	Reject Ho
Corrected for Ties	3	18.9939	0.000274	Reject Ho

Number Sets of Ties 8

Multiplicity Factor 23514

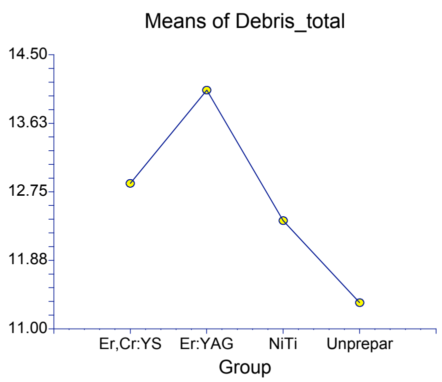
Group Detail

Group	Count	Sum of Ranks	Mean Rank	Z-Value	Median
Er,Cr:YSGG	21	912.50	43.45	0.2066	13
Er:YAG	21	1246.50	59.36	3.6568	15
NiTi	21	832.50	39.64	-0.6198	13
Unprepared	21	578.50	27.55	-3.2436	12

Means and Effects Section

Term	Count	Mean	Standard Error	Effect
All	84	12.65476		0.6026077
A: Group				
Er,Cr:YSGG	21	12.85714	0.4061601	12.25453
Er:YAG	21	14.04762	0.4061601	13.44501
NiTi	21	12.38095	0.4061601	11.77835
Unprepared	21	11.33333	0.4061601	10.73073

Plots of Means Section



Kruskal-Wallis Multiple-Comparison Z-Value Test

Debris_total	Er,Cr:YSGG	Er:YAG	NiTi	Unprepared
Er,Cr:YSGG	0.0000	2.1560	0.5164	2.1560
Er:YAG	2.1560	0.0000	2.6724	4.3121
NiTi	0.5164	2.6724	0.0000	1.6396
Unprepared	2.1560	4.3121	1.6396	0.0000

Regular Test: Medians significantly different if z-value > 1.9600

Bonferroni Test: Medians significantly different if z-value > 2.6383

Result

Modified-Levene Equal-Variance Test suggests that the assumption of equal variance is not met therefore Kruskal-wallis may not be valid. However the samples are of equal sizes should nullify this [1]. Alternatively use Mann-Whitney U test and reduce alpha for multiple comparisons.

Smear Analysis of variance report

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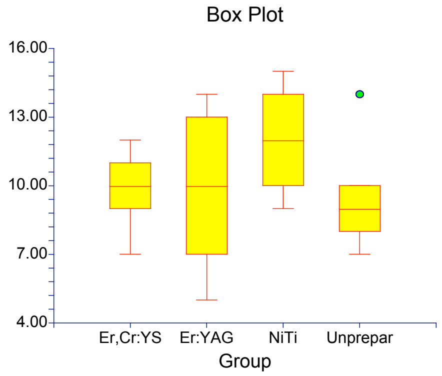
Database

Response Smear_total

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	0.4431	0.657722	Accept
Kurtosis Normality of Residuals	-0.8394	0.401266	Accept
Omnibus Normality of Residuals	0.9008	0.637363	Accept
Modified-Levene Equal-Variance Test	3.6283	0.016420	Reject

Box Plot Section



Kruskal-Wallis One-Way ANOVA on Ranks

Hypotheses

Ho: All medians are equal.

Ha: At least two medians are different.

Test Results

Method	DF	Chi-Square (H)	Prob Level	Decision(0.05)
Not Corrected for Ties	3	14.51441	0.002282	Reject Ho
Corrected for Ties	3	14.84291	0.001956	Reject Ho

Number Sets of Ties 10

Multiplicity Factor 13116

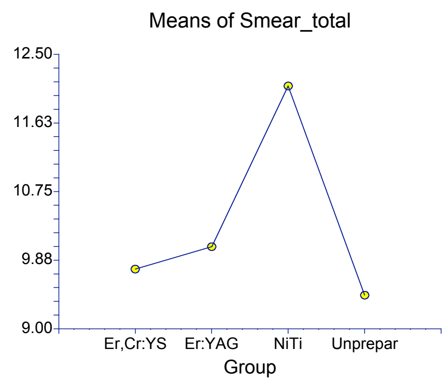
Group Detail

Group	Count	Sum of Ranks	Mean Rank	Z-Value	Median
Er,Cr:YSGG	21	790.50	37.64	-1.0537	10
Er:YAG	21	851.50	40.55	-0.4235	10
NiTi	21	1246.00	59.33	3.6517	12
Unprepared	21	682.00	32.48	-2.1745	9

Means and Effects Section

Term	Count	Mean	Standard Error	Effect
All	84	10.33333		0.4920635
A: Group				
Er,Cr:YSGG	21	9.761905	0.4938396	9.269841
Er:YAG	21	10.04762	0.4938396	9.555555
NiTi	21	12.09524	0.4938396	11.60317
Unprepared	21	9.428572	0.4938396	8.936508

Plots of Means Section



Kruskal-Wallis Multiple-Comparison Z-Value Test

Smear_total	Er,Cr:YSGG	Er:YAG	NiTi	Unprepared
Er,Cr:YSGG	0.0000	0.3902	2.9138	0.6941
Er:YAG	0.3902	0.0000	2.5236	1.0843
NiTi	2.9138	2.5236	0.0000	3.6079
Unprepared	0.6941	1.0843	3.6079	0.0000

Regular Test: Medians significantly different if z-value > 1.9600

Bonferroni Test: Medians significantly different if z-value > 2.6383

Result

Modified-Levene Equal-Variance Test suggests that the assumption of equal variance is not met therefore Kruskal-wallis may not be valid. However the samples are of equal sizes should nullify this [1]. Alternatively use Mann-Whitney U test and reduce alpha for multiple comparisons.

Overall total Analysis of variance report

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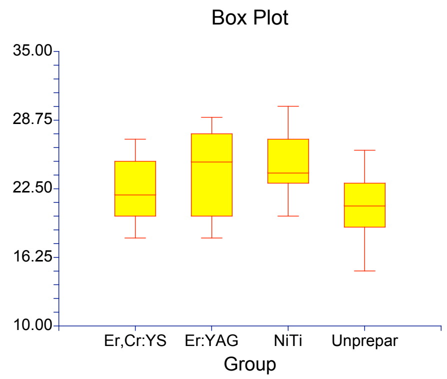
Database

Response Overall_total

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	-0.1548	0.876971	Accept
Kurtosis Normality of Residuals	-2.2002	0.027796	Reject
Omnibus Normality of Residuals	4.8647	0.087832	Accept
Modified-Levene Equal-Variance Test	0.6157	0.606821	Accept

Box Plot Section



Kruskal-Wallis One-Way ANOVA on Ranks

Hypotheses

Ho: All medians are equal.

Ha: At least two medians are different.

Test Results

Method	DF	Chi-Square (H)	Prob Level	Decision(0.05)
Not Corrected for Ties	3	13.61477	0.003479	Reject Ho
Corrected for Ties	3	13.81222	0.003172	Reject Ho

Number Sets of Ties 14

Multiplicity Factor 8472

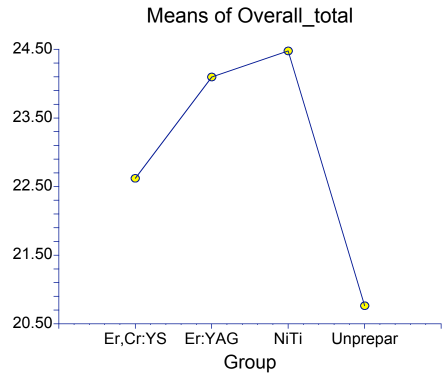
Group Detail

Group	Count	Sum of Ranks	Mean Rank	Z-Value	Median
Er,Cr:YSGG	21	835.50	39.79	-0.5888	22
Er:YAG	21	1055.50	50.26	1.6838	25
NiTi	21	1099.00	52.33	2.1331	24
Unprepared	21	580.00	27.62	-3.2281	21

Means and Effects Section

Term	Count	Mean	Standard Error	Effect
All	84	22.98809		1.094671
A: Group				
Er,Cr:YSGG	21	22.61905	0.6882558	21.52438
Er:YAG	21	24.09524	0.6882558	23.00057
NiTi	21	24.47619	0.6882558	23.38152
Unprepared	21	20.76191	0.6882558	19.66723

Plots of Means Section



Kruskal-Wallis Multiple-Comparison Z-Value Test

Overall_total	Er,Cr:YSGG	Er:YAG	NiTi	Unprepared
Er,Cr:YSGG	0.0000	1.4017	1.6789	1.6279
Er:YAG	1.4017	0.0000	0.2772	3.0297
NiTi	1.6789	0.2772	0.0000	3.3068
Unprepared	1.6279	3.0297	3.3068	0.0000

Regular Test: Medians significantly different if z-value > 1.9600

Bonferroni Test: Medians significantly different if z-value > 2.6383

Result

The median overall total score for Er:YAG is significantly greater than the Unprepared group.

The median overall total score for NiTi is significantly greater than the Unprepared group.

The median overall total score for Er,Cr:YSGG is not significantly different from Er:YAG, NiTi or Unprepared.

The median overall total score for Er:YAG is not significantly different from NiTi.

Er:YAG > Unprepared

NiTi > Unprepared

Debris Two-sample test report

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Variable Debris_total

Er,Cr:YSGG v Er:YAG

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	12.85714	1.651839	0.3604608	11.80139	13.9129
Group=Er:YAG	21	14.04762	1.283596	0.2801037	13.22722	14.86802

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Er:YAG) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.0637	0.949213	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.7893	0.073571	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	3.2056	0.201336	Cannot reject normality
Skewness Normality (Group=Er:YAG)	-2.9752	0.002928	Reject normality
Kurtosis Normality (Group=Er:YAG)	2.4200	0.015520	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	14.7082	0.000640	Reject normality
Variance-Ratio Equal-Variance Test	1.6561	0.267765	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.8766	0.354763	Cannot reject equal variances

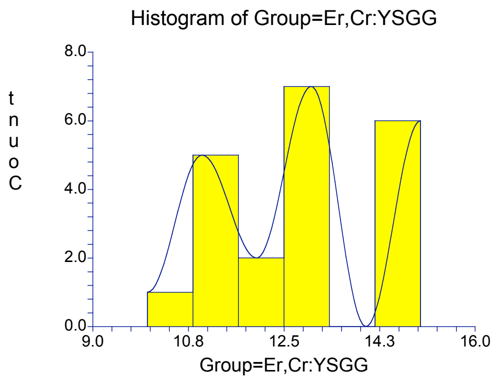
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

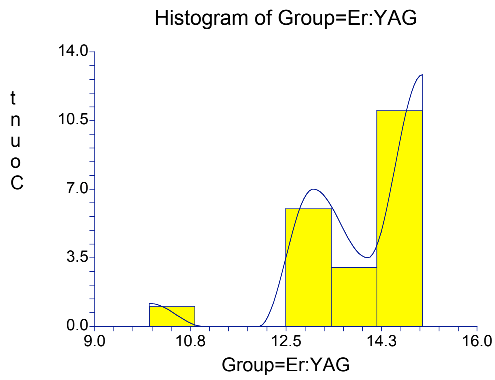
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	128.5	359.5	451.5	37.76007
Group=Er:YAG	312.5	543.5	451.5	37.76007

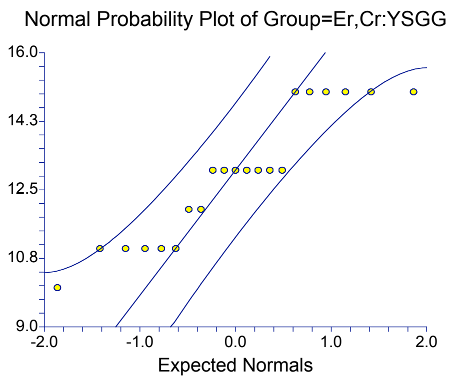
Number Sets of Ties = 6, Multiplicity Factor = 7236

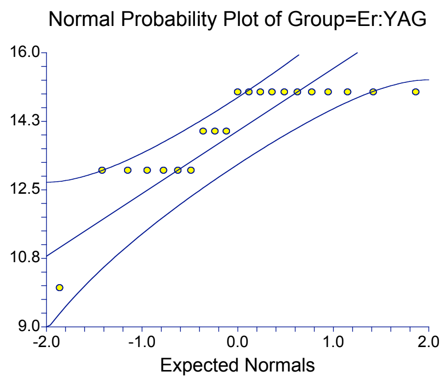
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-2.4364	0.014833	Accept Ho	-2.4232	0.015385	Accept Ho
Diff<0	-2.4364	0.007416	Reject Ho	-2.4232	0.007692	Reject Ho
Diff>0	-2.4364	0.992584	Accept Ho	-2.4497	0.992851	Accept Ho

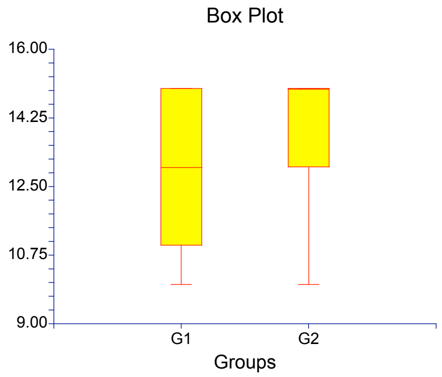
Plots Section










Box Plot
16.00
14.25
12.50
10.75
9.00
G1
G2
Groups

Er,Cr:YSGG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	12.85714	1.651839	0.3604608	11.80139	13.9129
Group=NiTi	21	12.38095	2.312492	0.5046271	10.90294	13.85896

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.0637	0.949213	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.7893	0.073571	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	3.2056	0.201336	Cannot reject normality
Skewness Normality (Group=NiTi)	-0.4100	0.681817	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-3.1039	0.001910	Reject normality
Omnibus Normality (Group=NiTi)	9.8020	0.007439	Reject normality
Variance-Ratio Equal-Variance Test	1.9599	0.140910	Cannot reject equal variances
Modified-Levene Equal-Variance Test	5.1613	0.028547	Cannot reject equal variances

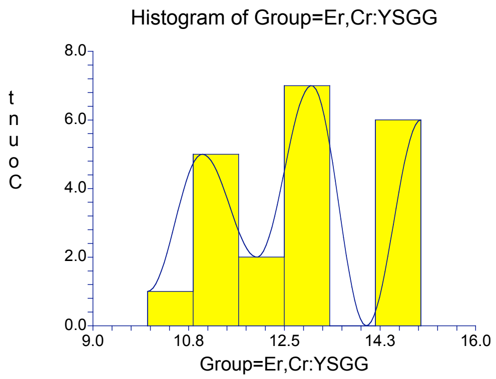
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

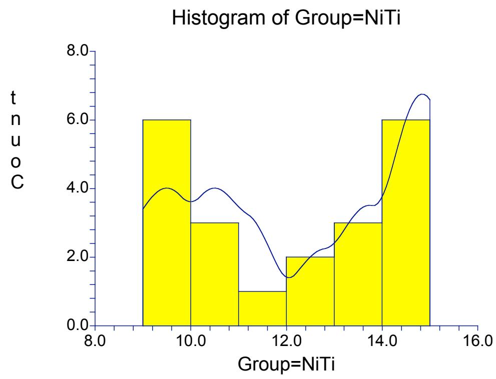
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	246	477	451.5	38.91901
Group=NiTi	195	426	451.5	38.91901

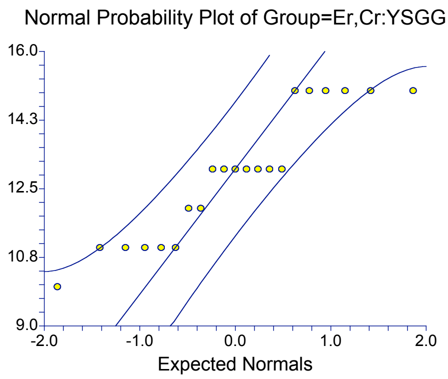
Number Sets of Ties = 7, Multiplicity Factor = 3072

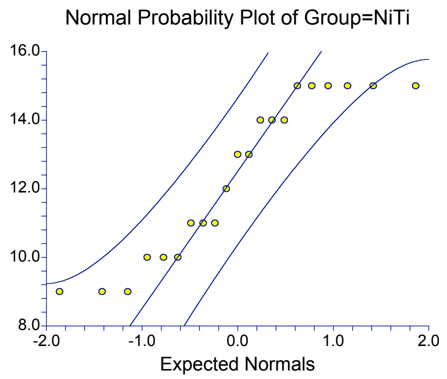
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	0.6552	0.512335	Accept Ho	0.6424	0.520640	Accept Ho
Diff<0	0.6552	0.743833	Accept Ho	0.6681	0.747950	Accept Ho
Diff>0	0.6552	0.256167	Accept Ho	0.6424	0.260320	Accept Ho

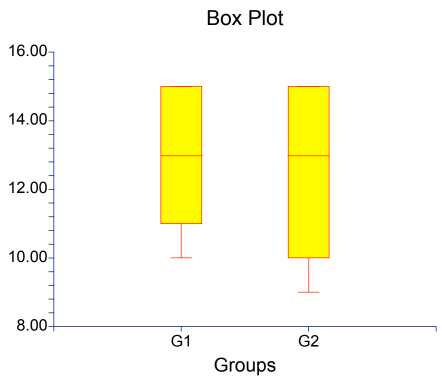
Plots Section











Er,Cr:YSGG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	12.85714	1.651839	0.3604608	11.80139	13.9129
Group=Unprepared	21	11.33333	2.03306	0.4436501	10.03392	12.63274

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.0637	0.949213	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.7893	0.073571	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	3.2056	0.201336	Cannot reject normality
Skewness Normality (Group=Unprepared)	-1.8564	0.063399	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.5919	0.553906	Cannot reject normality
Omnibus Normality (Group=Unprepared)	3.7965	0.149828	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.5148	0.360770	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.3748	0.543857	Cannot reject equal variances

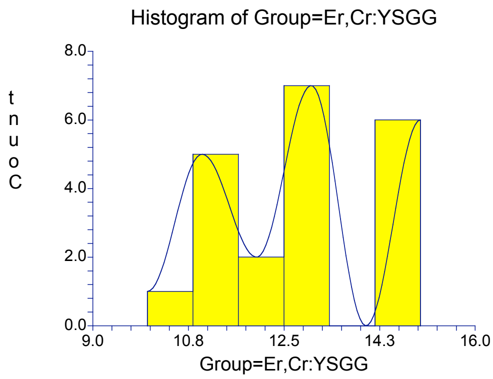
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

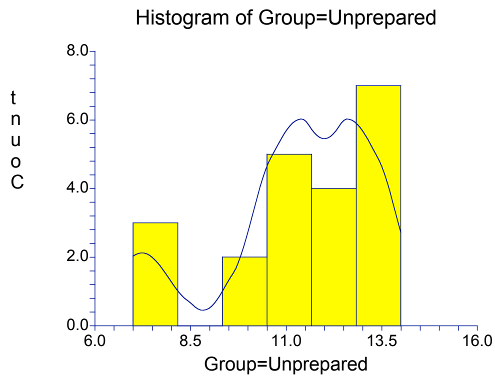
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	307	538	451.5	38.89432
Group=Unprepared	134	365	451.5	38.89432

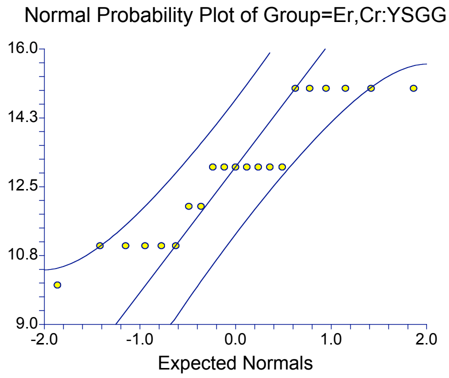
Number Sets of Ties = 7, Multiplicity Factor = 3162

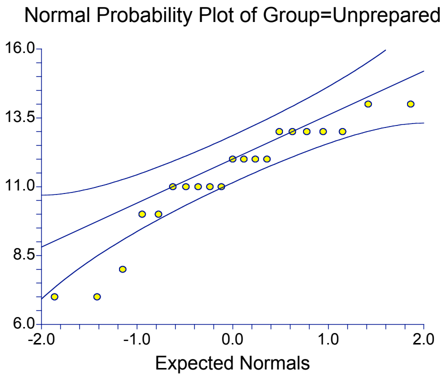
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	2.2240	0.026150	Accept Ho	2.2111	0.027028	Accept Ho
Diff<0	2.2240	0.986925	Accept Ho	2.2368	0.987351	Accept Ho
Diff>0	2.2240	0.013075	Accept Ho	2.2111	0.013514	Accept Ho

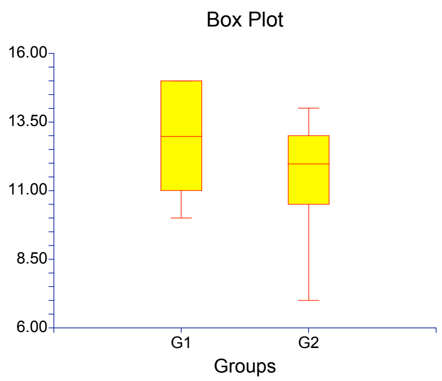
Plots Section











Er:YAG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	14.04762	1.283596	0.2801037	13.22722	14.86802
Group=NiTi	21	12.38095	2.312492	0.5046271	10.90294	13.85896

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-2.9752	0.002928	Reject normality
Kurtosis Normality (Group=Er:YAG)	2.4200	0.015520	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	14.7082	0.000640	Reject normality
Skewness Normality (Group=NiTi)	-0.4100	0.681817	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-3.1039	0.001910	Reject normality
Omnibus Normality (Group=NiTi)	9.8020	0.007439	Reject normality
Variance-Ratio Equal-Variance Test	3.2457	0.011373	Cannot reject equal variances
Modified-Levene Equal-Variance Test	8.4102	0.006035	Reject equal variances

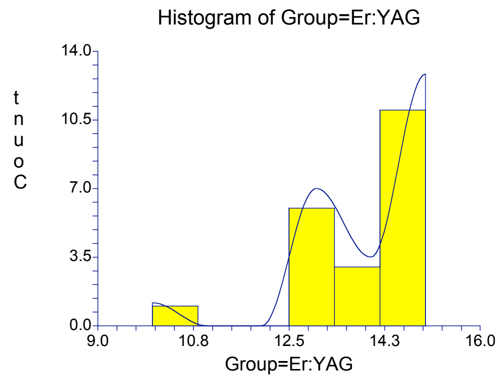
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

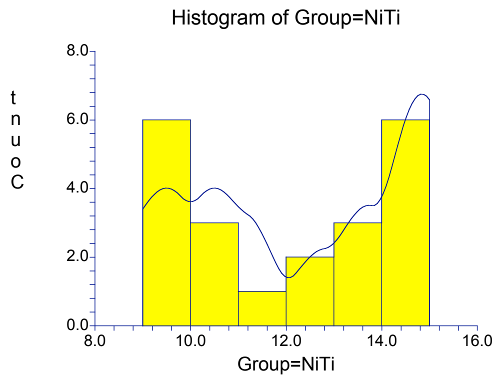
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	309	540	451.5	38.18664
Group=NiTi	132	363	451.5	38.18664

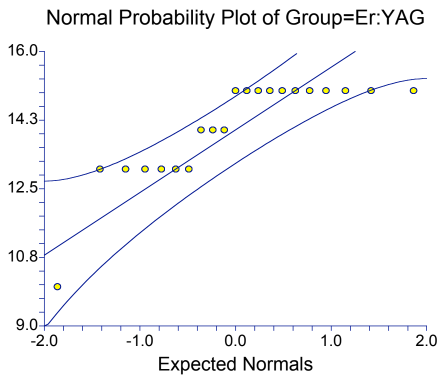
Number Sets of Ties = 6, Multiplicity Factor = 5718

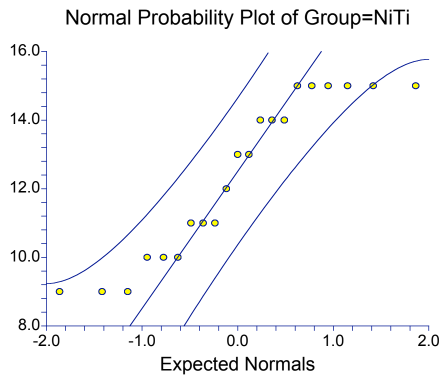
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	2.3176	0.020473	Accept Ho	2.3045	0.021196	Accept Ho
Diff<0	2.3176	0.989763	Accept Ho	2.3307	0.990114	Accept Ho
Diff>0	2.3176	0.010237	Accept Ho	2.3045	0.010598	Accept Ho

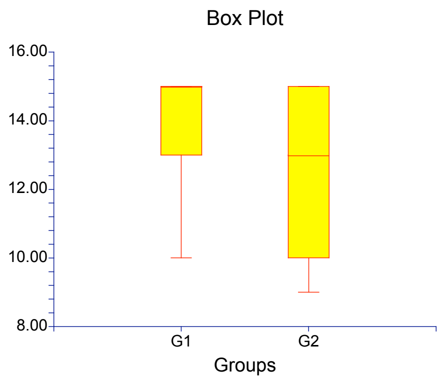
Plots Section











Er:YAG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	14.04762	1.283596	0.2801037	13.22722	14.86802
Group=Unprepared	21	11.33333	2.03306	0.4436501	10.03392	12.63274

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-2.9752	0.002928	Reject normality
Kurtosis Normality (Group=Er:YAG)	2.4200	0.015520	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	14.7082	0.000640	Reject normality
Skewness Normality (Group=Unprepared)	-1.8564	0.063399	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.5919	0.553906	Cannot reject normality
Omnibus Normality (Group=Unprepared)	3.7965	0.149828	Cannot reject normality
Variance-Ratio Equal-Variance Test	2.5087	0.045788	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.8000	0.187280	Cannot reject equal variances

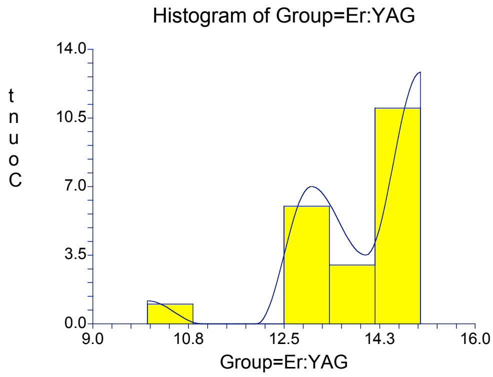
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

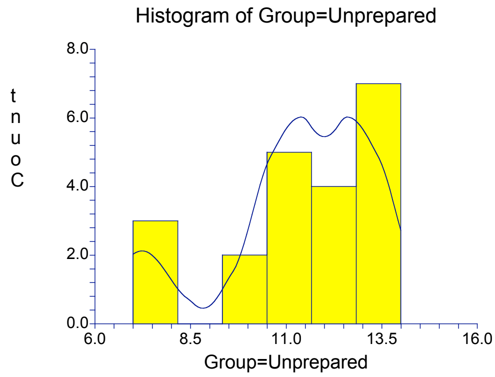
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	394	625	451.5	38.94696
Group=Unprepared	47	278	451.5	38.94696

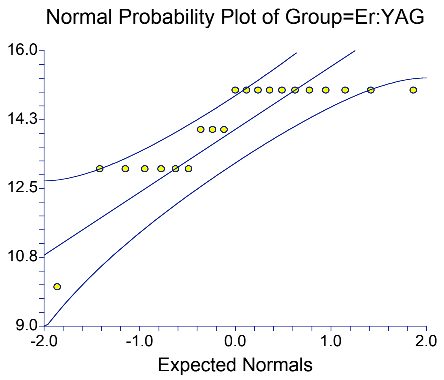
Number Sets of Ties = 7, Multiplicity Factor = 2970

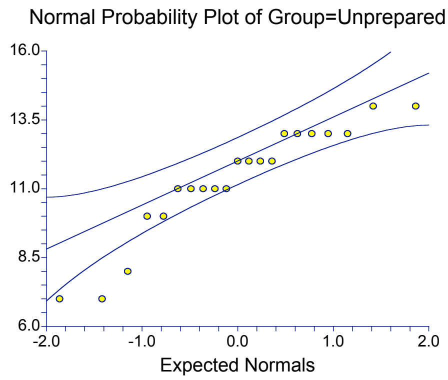
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	4.4548	0.000008	Reject Ho	4.4419	0.000009	Reject Ho
Diff<0	4.4548	0.999996	Accept Ho	4.4676	0.999996	Accept Ho
Diff>0	4.4548	0.000004	Reject Ho	4.4419	0.000004	Reject Ho

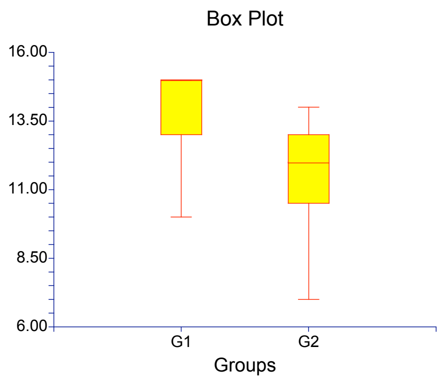
Plots Section











NiTi v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=NiTi	21	12.38095	2.312492	0.5046271	10.90294	13.85896
Group=Unprepared	21	11.33333	2.03306	0.4436501	10.03392	12.63274

Note: T-alpha (Group=NiTi) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=NiTi)	-0.4100	0.681817	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-3.1039	0.001910	Reject normality
Omnibus Normality (Group=NiTi)	9.8020	0.007439	Reject normality
Skewness Normality (Group=Unprepared)	-1.8564	0.063399	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.5919	0.553906	Cannot reject normality
Omnibus Normality (Group=Unprepared)	3.7965	0.149828	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.2938	0.570026	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.6418	0.207458	Cannot reject equal variances

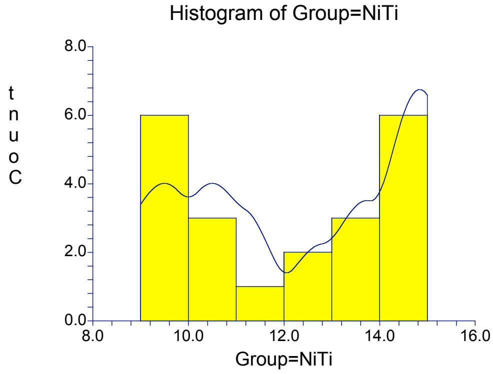
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

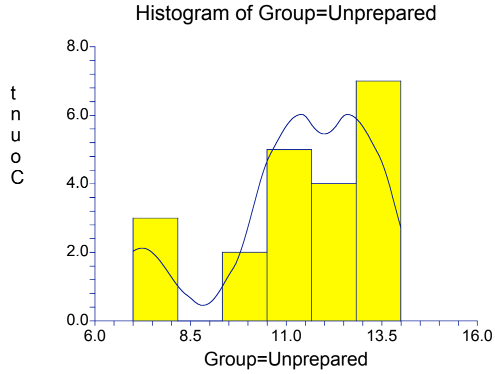
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=NiTi	274.5	505.5	451.5	39.36392
Group=Unprepared	166.5	397.5	451.5	39.36392

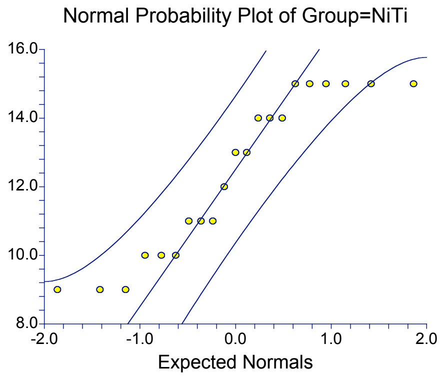
Number Sets of Ties = 8, Multiplicity Factor = 1440

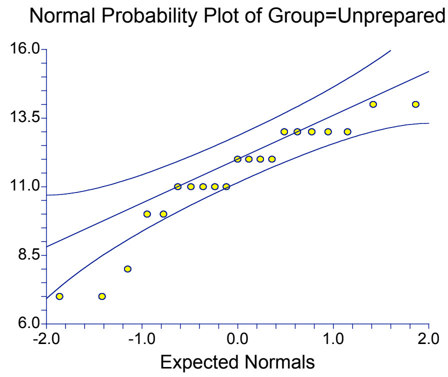
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	1.3718	0.170121	Accept Ho	1.3591	0.174111	Accept Ho
Diff<0	1.3718	0.914939	Accept Ho	1.3845	0.916900	Accept Ho
Diff>0	1.3718	0.085061	Accept Ho	1.3591	0.087055	Accept Ho

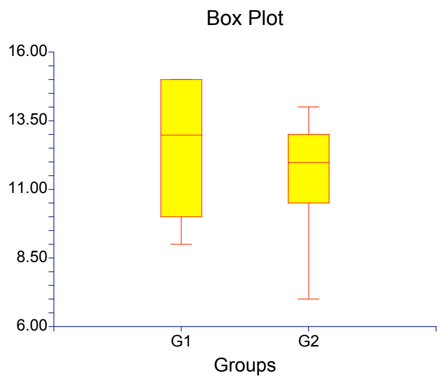
Plots Section











Result

The median debris total score for Er,Cr:YSGG is not significantly different from the Er:YAG, NiTi, or Unprepared groups.

The median debris total score for Er:YAG is not significantly different from NiTi.

The median debris total score for Er:YAG is significantly greater than the Unprepared group.

The median debris total score for NiTi is not significantly different from Unprepared group.

Er:YAG > Unprepared

Smear Two-sample test report

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Variable Smear_total

Er,Cr:YSGG v Er:YAG

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	9.761905	1.513432	0.3302579	8.794609	10.7292
Group=Er:YAG	21	10.04762	2.940683	0.6417097	8.168109	11.92713

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Er:YAG) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.8661	0.386445	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	0.0227	0.981866	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	0.7506	0.687078	Cannot reject normality
Skewness Normality (Group=Er:YAG)	-0.4395	0.660277	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.5905	0.111725	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	2.7228	0.256297	Cannot reject normality
Variance-Ratio Equal-Variance Test	3.7755	0.004558	Reject equal variances
Modified-Levene Equal-Variance Test	10.5235	0.002383	Reject equal variances

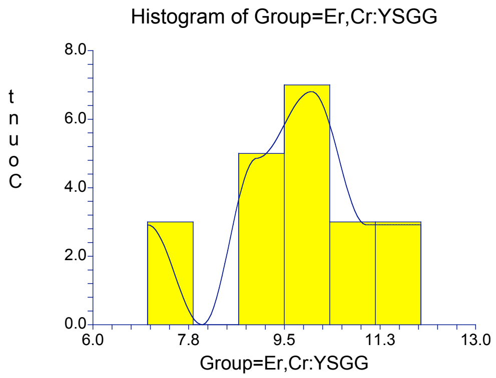
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

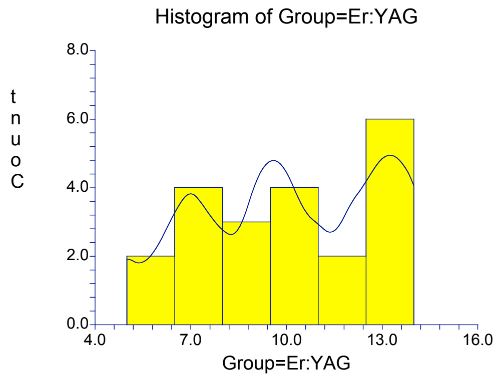
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	202.5	433.5	451.5	39.1944
Group=Er:YAG	238.5	469.5	451.5	39.1944

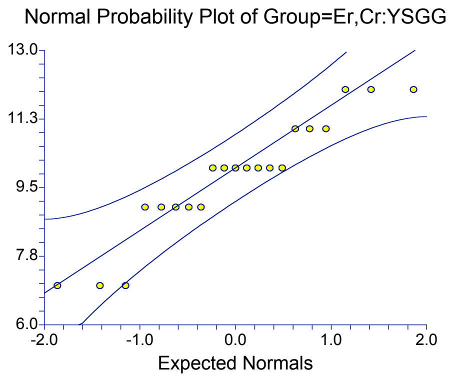
Number Sets of Ties = 8, Multiplicity Factor = 2064

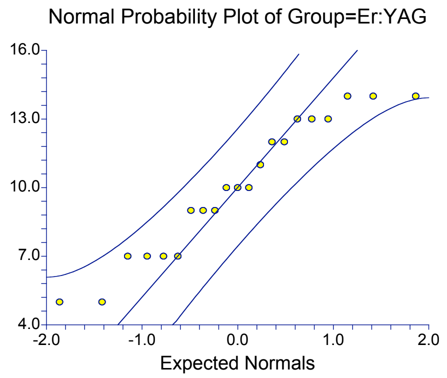
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-0.4592	0.646055	Accept Ho	-0.4465	0.655242	Accept Ho
Diff<0	-0.4592	0.323028	Accept Ho	-0.4465	0.327621	Accept Ho
Diff>0	-0.4592	0.676972	Accept Ho	-0.4720	0.681539	Accept Ho

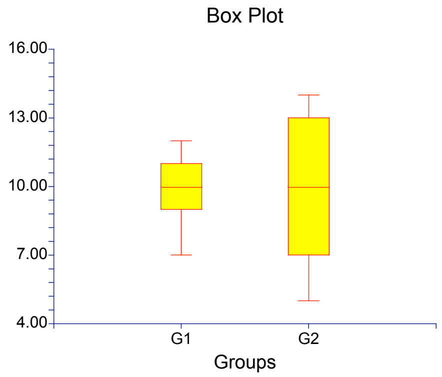
Plots Section











Box Plot
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G1
G2
Groups

Er,Cr:YSGG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	9.761905	1.513432	0.3302579	8.794609	10.7292
Group=NiTi	21	12.09524	2.14254	0.4675405	10.72585	13.46462

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.8661	0.386445	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	0.0227	0.981866	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	0.7506	0.687078	Cannot reject normality
Skewness Normality (Group=NiTi)	0.0685	0.945356	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-1.9713	0.048689	Cannot reject normality
Omnibus Normality (Group=NiTi)	3.8908	0.142933	Cannot reject normality
Variance-Ratio Equal-Variance Test	2.0042	0.128409	Cannot reject equal variances
Modified-Levene Equal-Variance Test	4.7569	0.035120	Cannot reject equal variances

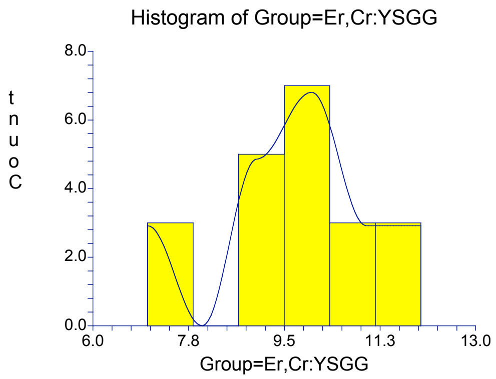
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

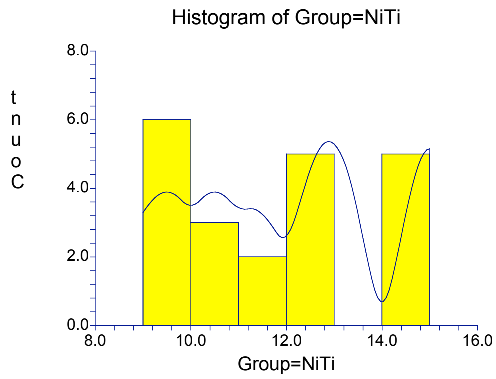
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	91.5	322.5	451.5	39.18787
Group=NiTi	349.5	580.5	451.5	39.18787

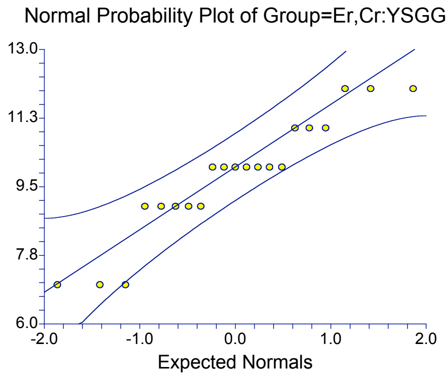
Number Sets of Ties = 7, Multiplicity Factor = 2088

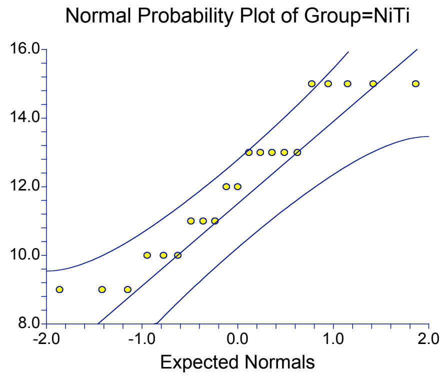
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-3.2918	0.000995	Reject Ho	-3.2791	0.001041	Reject Ho
Diff<0	-3.2918	0.000498	Reject Ho	-3.2791	0.000521	Reject Ho
Diff>0	-3.2918	0.999502	Accept Ho	-3.3046	0.999524	Accept Ho

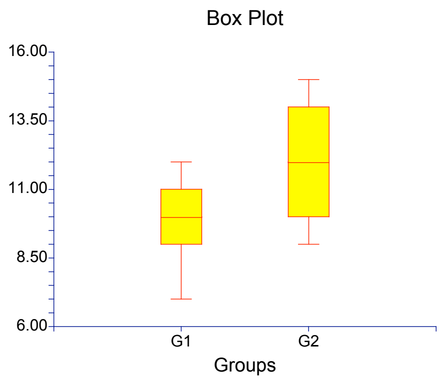
Plots Section











Er,Cr:YSGG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	9.761905	1.513432	0.3302579	8.794609	10.7292
Group=Unprepared	21	9.428572	2.226464	0.4858543	8.005548	10.85159

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	-0.8661	0.386445	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	0.0227	0.981866	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	0.7506	0.687078	Cannot reject normality
Skewness Normality (Group=Unprepared)	2.1020	0.035555	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.7612	0.446511	Cannot reject normality
Omnibus Normality (Group=Unprepared)	4.9978	0.082175	Cannot reject normality
Variance-Ratio Equal-Variance Test	2.1642	0.092040	Cannot reject equal variances
Modified-Levene Equal-Variance Test	2.0630	0.158685	Cannot reject equal variances

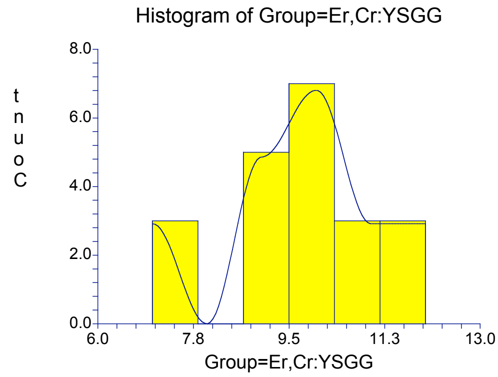
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

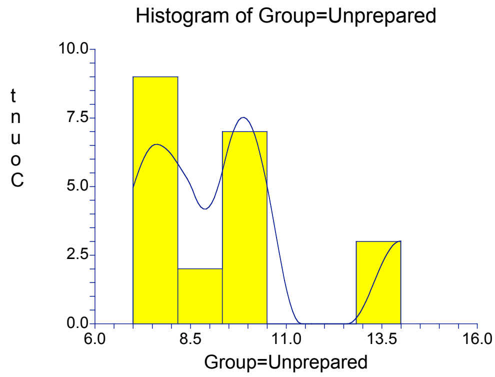
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	265.5	496.5	451.5	38.77562
Group=Unprepared	175.5	406.5	451.5	38.77562

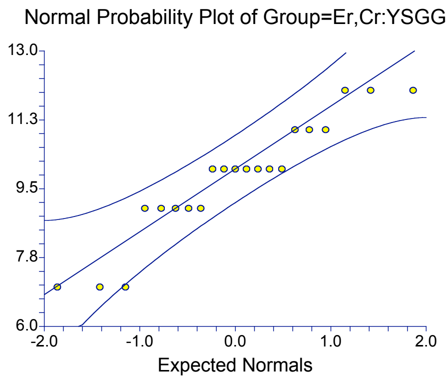
Number Sets of Ties = 7, Multiplicity Factor = 3594

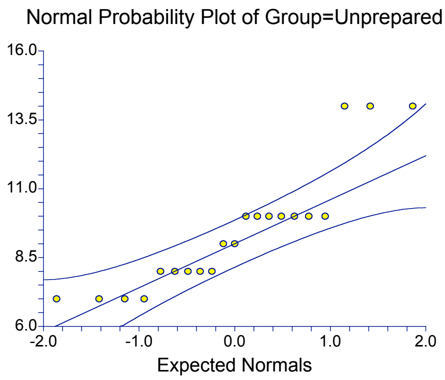
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	1.1605	0.245836	Accept Ho	1.1476	0.251122	Accept Ho
Diff<0	1.1605	0.877082	Accept Ho	1.1734	0.879686	Accept Ho
Diff>0	1.1605	0.122918	Accept Ho	1.1476	0.125561	Accept Ho

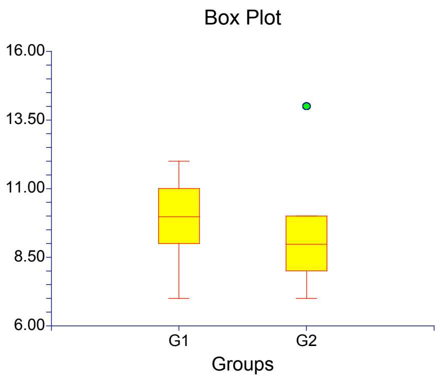
Plots Section











Er:YAG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	10.04762	2.940683	0.6417097	8.168109	11.92713
Group=NiTi	21	12.09524	2.14254	0.4675405	10.72585	13.46462

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-0.4395	0.660277	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.5905	0.111725	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	2.7228	0.256297	Cannot reject normality
Skewness Normality (Group=NiTi)	0.0685	0.945356	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-1.9713	0.048689	Cannot reject normality
Omnibus Normality (Group=NiTi)	3.8908	0.142933	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.8838	0.165370	Cannot reject equal variances
Modified-Levene Equal-Variance Test	2.2237	0.143753	Cannot reject equal variances

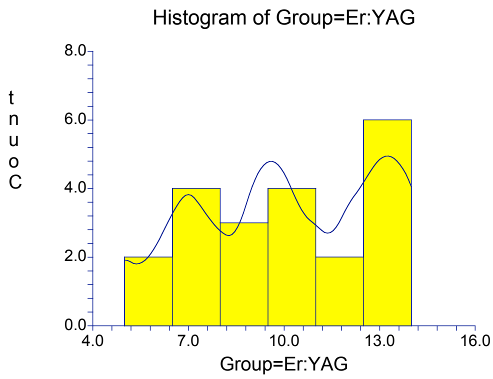
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

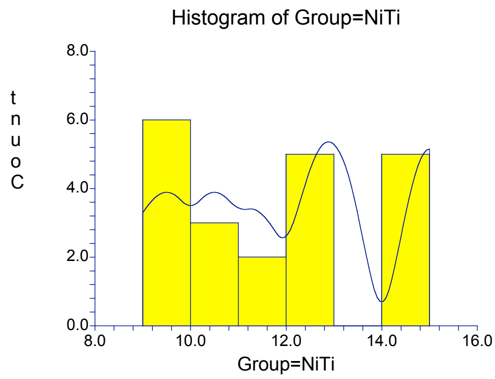
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	134	365	451.5	39.41431
Group=NiTi	307	538	451.5	39.41431

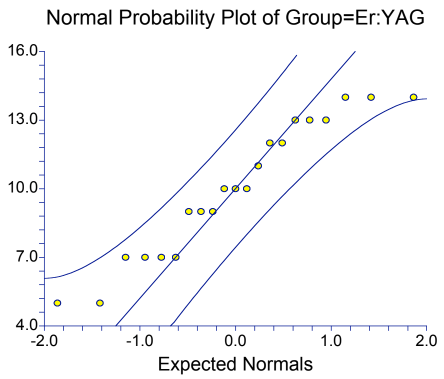
Number Sets of Ties = 9, Multiplicity Factor = 1254

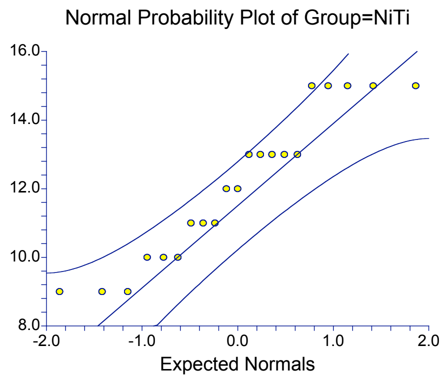
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-2.1946	0.028190	Accept Ho	-2.1819	0.029113	Accept Ho
Diff<0	-2.1946	0.014095	Accept Ho	-2.1819	0.014557	Accept Ho
Diff>0	-2.1946	0.985905	Accept Ho	-2.2073	0.986354	Accept Ho

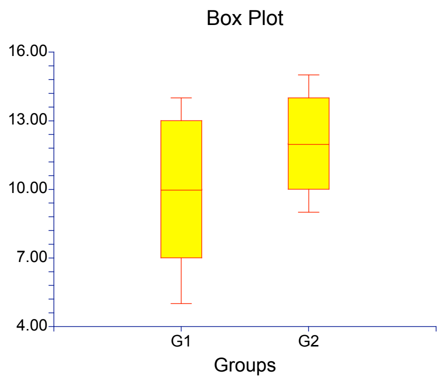
Plots Section











Er:YAG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	10.04762	2.940683	0.6417097	8.168109	11.92713
Group=Unprepared	21	9.428572	2.226464	0.4858543	8.005548	10.85159

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-0.4395	0.660277	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.5905	0.111725	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	2.7228	0.256297	Cannot reject normality
Skewness Normality (Group=Unprepared)	2.1020	0.035555	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.7612	0.446511	Cannot reject normality
Omnibus Normality (Group=Unprepared)	4.9978	0.082175	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.7445	0.222038	Cannot reject equal variances
Modified-Levene Equal-Variance Test	2.5990	0.114796	Cannot reject equal variances

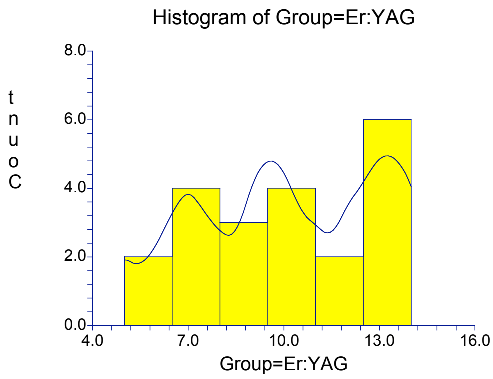
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

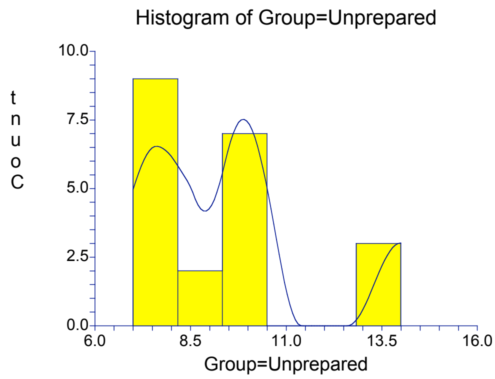
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	248	479	451.5	39.21727
Group=Unprepared	193	424	451.5	39.21727

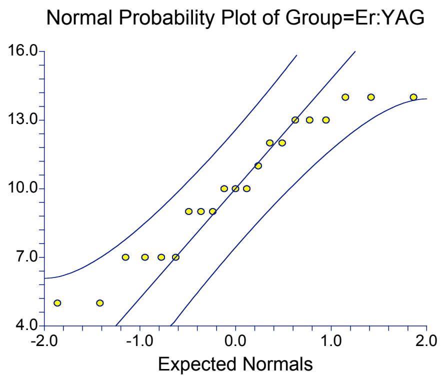
Number Sets of Ties = 8, Multiplicity Factor = 1980

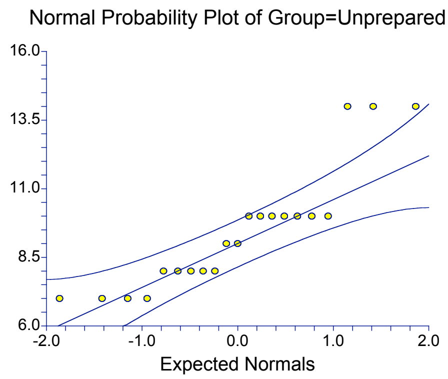
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	0.7012	0.483165	Accept Ho	0.6885	0.491155	Accept Ho
Diff<0	0.7012	0.758418	Accept Ho	0.7140	0.762378	Accept Ho
Diff>0	0.7012	0.241582	Accept Ho	0.6885	0.245578	Accept Ho

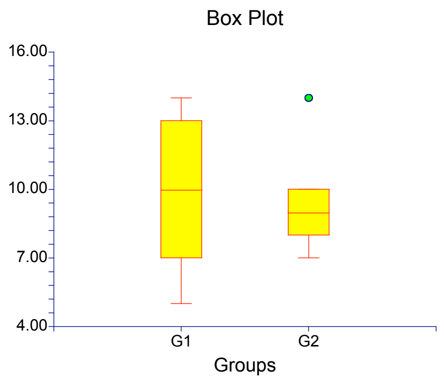
Plots Section











NiTi v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=NiTi	21	12.09524	2.14254	0.4675405	10.72585	13.46462
Group=Unprepared	21	9.428572	2.226464	0.4858543	8.005548	10.85159

Note: T-alpha (Group=NiTi) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=NiTi)	0.0685	0.945356	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-1.9713	0.048689	Cannot reject normality
Omnibus Normality (Group=NiTi)	3.8908	0.142933	Cannot reject normality
Skewness Normality (Group=Unprepared)	2.1020	0.035555	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.7612	0.446511	Cannot reject normality
Omnibus Normality (Group=Unprepared)	4.9978	0.082175	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.0799	0.865263	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.1262	0.724243	Cannot reject equal variances

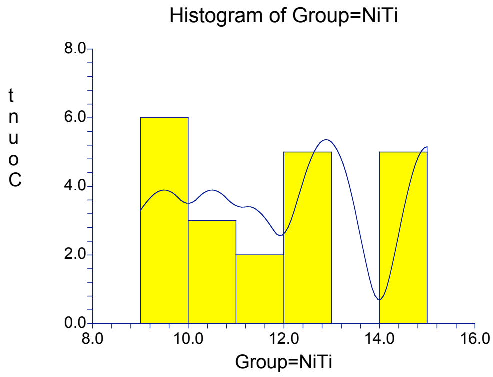
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

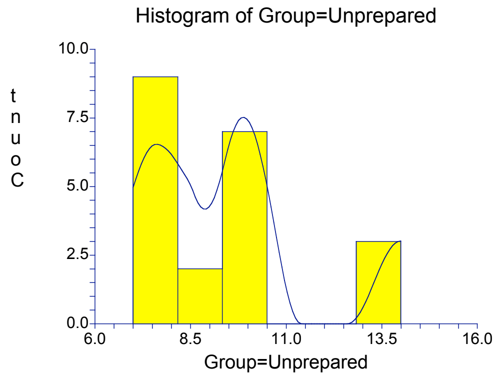
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=NiTi	358.5	589.5	451.5	39.32487
Group=Unprepared	82.5	313.5	451.5	39.32487

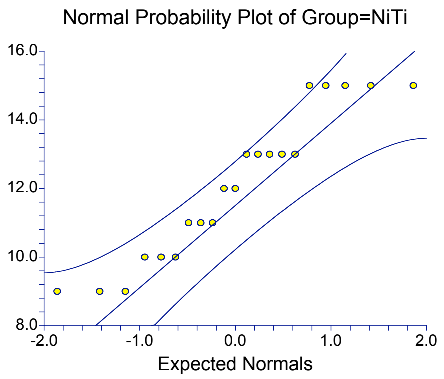
Number Sets of Ties = 9, Multiplicity Factor = 1584

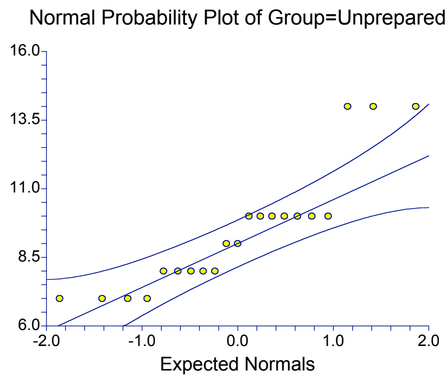
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	3.5092	0.000449	Reject Ho	3.4965	0.000471	Reject Ho
Diff<0	3.5092	0.999775	Accept Ho	3.5219	0.999786	Accept Ho
Diff>0	3.5092	0.000225	Reject Ho	3.4965	0.000236	Reject Ho

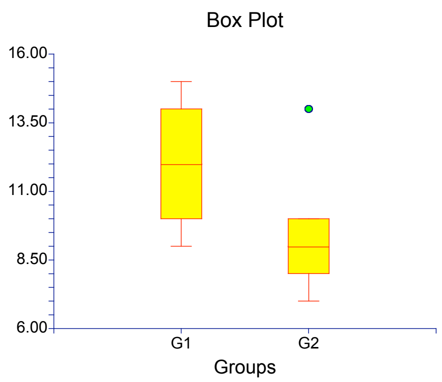
Plots Section











Result

The median smear total score for Er,Cr:YSGG is not significantly different from the Er:YAG, or Unprepared groups.

The median smear total score for Er,Cr:YSGG is significantly less than the NiTi group.

The median smear total score for Er:YAG is not significantly different from NiTi, or Unprepared groups.

The median smear total score for NiTi is significantly greater than the Unprepared group.

E,Cr:YSGG < NiTi

NiTi > Unprepared

Overall total Two-sample test report

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Variable Overall_total

Er,Cr:YSGG v Er:YAG

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	22.61905	2.765433	0.6034669	20.85155	24.38655
Group=Er:YAG	21	24.09524	3.618076	0.789529	21.78278	26.4077

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Er:YAG) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.3317	0.740142	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.5372	0.124243	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	2.4730	0.290398	Cannot reject normality
Skewness Normality (Group=Er:YAG)	-0.6355	0.525103	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.7261	0.084332	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	3.3832	0.184221	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.7117	0.238000	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.3659	0.249444	Cannot reject equal variances

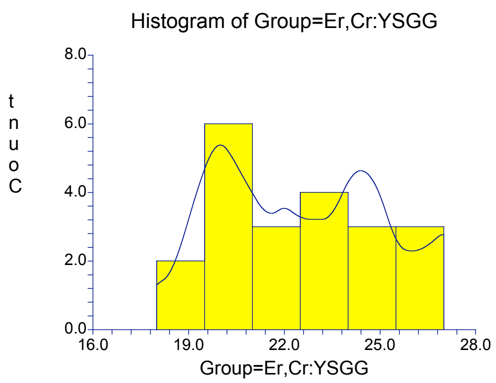
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

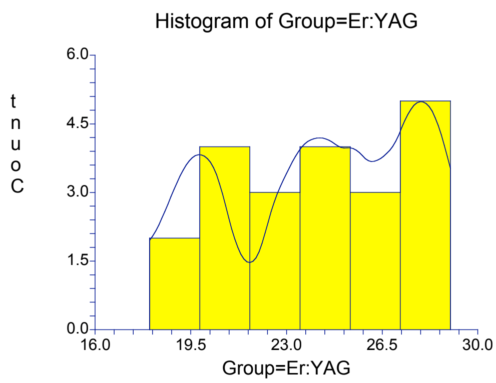
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	162.5	393.5	451.5	39.41594
Group=Er:YAG	278.5	509.5	451.5	39.41594

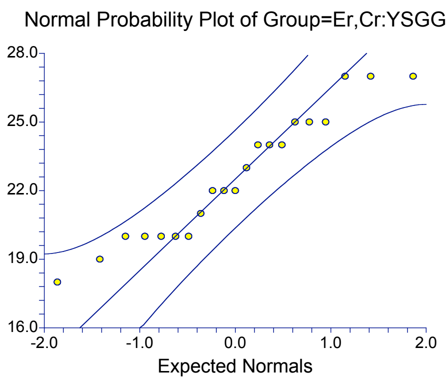
Number Sets of Ties = 9, Multiplicity Factor = 1248

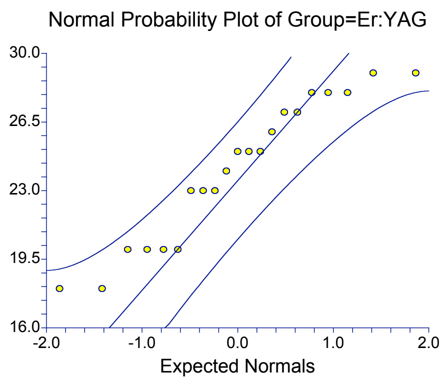
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-1.4715	0.141160	Accept Ho	-1.4588	0.144620	Accept Ho
Diff<0	-1.4715	0.070580	Accept Ho	-1.4588	0.072310	Accept Ho
Diff>0	-1.4715	0.929420	Accept Ho	-1.4842	0.931118	Accept Ho

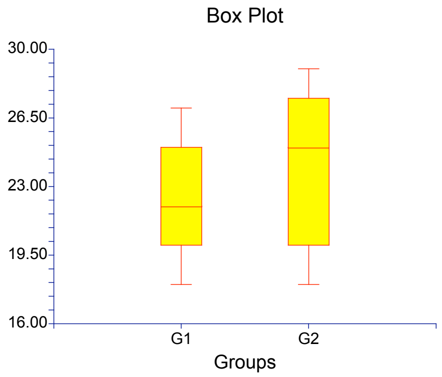
Plots Section










Box Plot
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G1
G2
Groups

Er,Cr:YSGG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	22.61905	2.765433	0.6034669	20.85155	24.38655
Group=NiTi	21	24.47619	3.140367	0.6852843	22.46906	26.48333

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.3317	0.740142	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.5372	0.124243	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	2.4730	0.290398	Cannot reject normality
Skewness Normality (Group=NiTi)	1.0302	0.302930	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-0.4460	0.655601	Cannot reject normality
Omnibus Normality (Group=NiTi)	1.2602	0.532549	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.2895	0.574938	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.0073	0.932118	Cannot reject equal variances

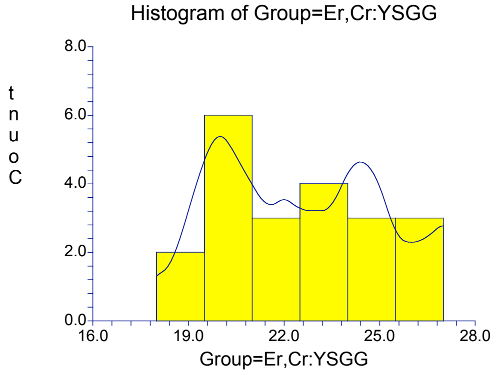
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

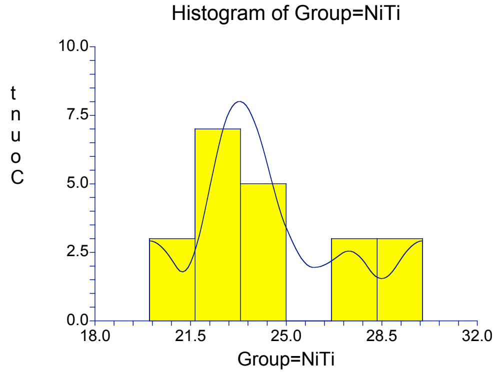
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	152.5	383.5	451.5	39.38181
Group=NiTi	288.5	519.5	451.5	39.38181

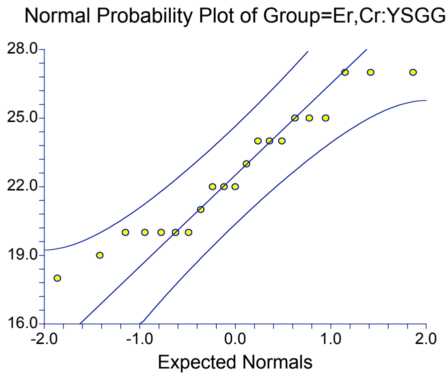
Number Sets of Ties = 7, Multiplicity Factor = 1374

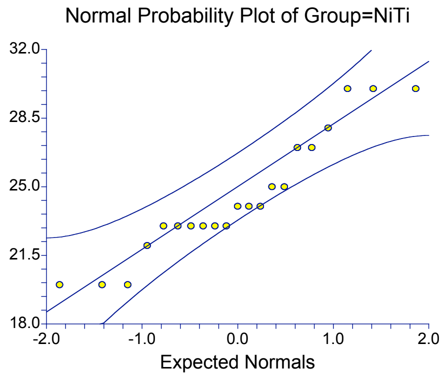
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-1.7267	0.084224	Accept Ho	-1.7140	0.086531	Accept Ho
Diff<0	-1.7267	0.042112	Accept Ho	-1.7140	0.043265	Accept Ho
Diff>0	-1.7267	0.957888	Accept Ho	-1.7394	0.959016	Accept Ho

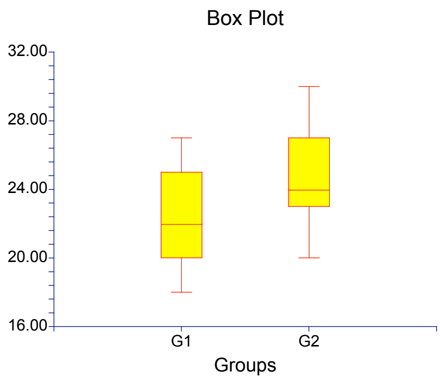
Plots Section











Er,Cr:YSGG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er,Cr:YSGG	21	22.61905	2.765433	0.6034669	20.85155	24.38655
Group=Unprepared	21	20.76191	3.03158	0.661545	18.8243	22.69951

Note: T-alpha (Group=Er,Cr:YSGG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er,Cr:YSGG)	0.3317	0.740142	Cannot reject normality
Kurtosis Normality (Group=Er,Cr:YSGG)	-1.5372	0.124243	Cannot reject normality
Omnibus Normality (Group=Er,Cr:YSGG)	2.4730	0.290398	Cannot reject normality
Skewness Normality (Group=Unprepared)	-0.7222	0.470198	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.0868	0.930864	Cannot reject normality
Omnibus Normality (Group=Unprepared)	0.5290	0.767575	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.2017	0.685076	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.0000	1.000000	Cannot reject equal variances

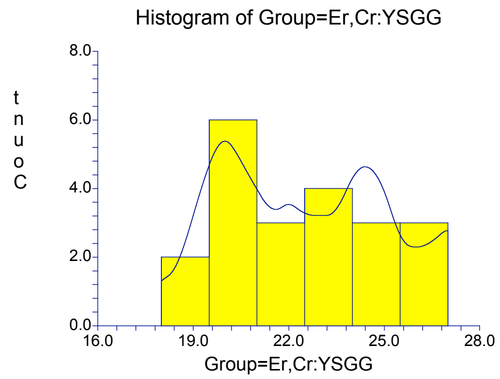
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

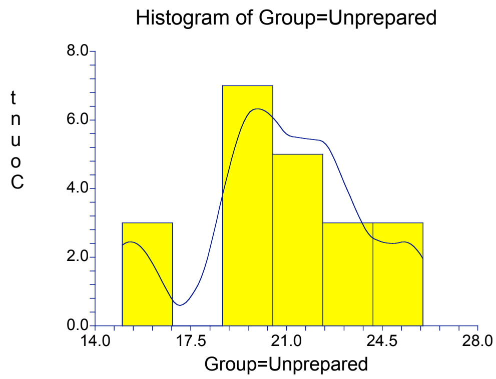
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er,Cr:YSGG	289.5	520.5	451.5	39.41594
Group=Unprepared	151.5	382.5	451.5	39.41594

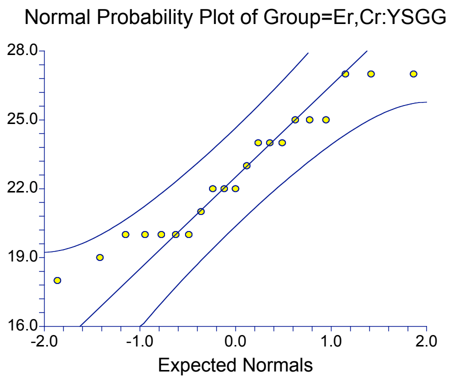
Number Sets of Ties = 9, Multiplicity Factor = 1248

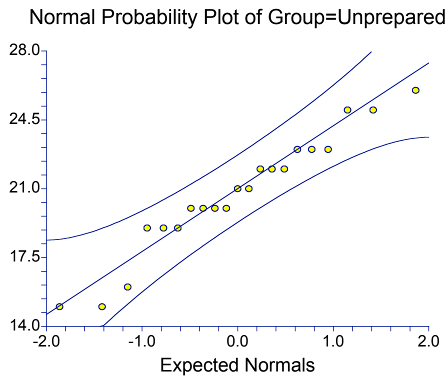
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	1.7506	0.080022	Accept Ho	1.7379	0.082233	Accept Ho
Diff<0	1.7506	0.959989	Accept Ho	1.7632	0.961071	Accept Ho
Diff>0	1.7506	0.040011	Accept Ho	1.7379	0.041116	Accept Ho

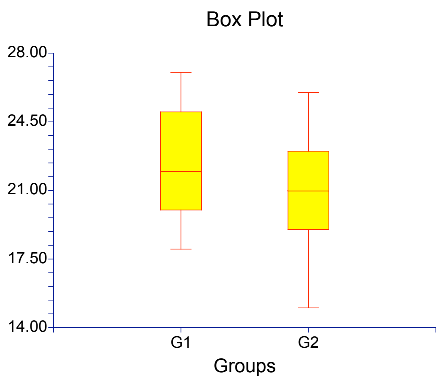
Plots Section











Er:YAG v NiTi

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	24.09524	3.618076	0.789529	21.78278	26.4077
Group=NiTi	21	24.47619	3.140367	0.6852843	22.46906	26.48333

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=NiTi) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-0.6355	0.525103	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.7261	0.084332	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	3.3832	0.184221	Cannot reject normality
Skewness Normality (Group=NiTi)	1.0302	0.302930	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-0.4460	0.655601	Cannot reject normality
Omnibus Normality (Group=NiTi)	1.2602	0.532549	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.3274	0.532380	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.9306	0.340499	Cannot reject equal variances

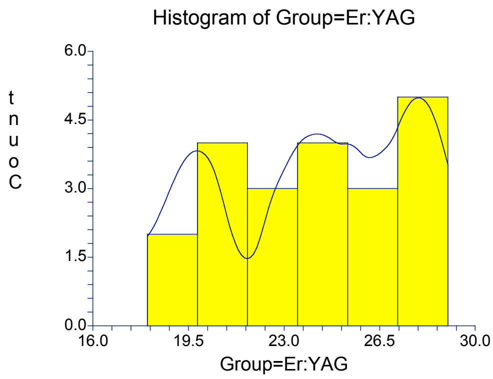
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

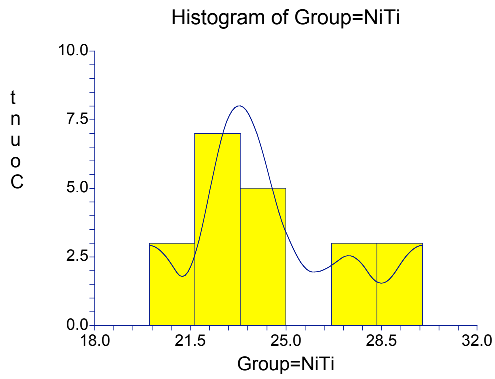
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	216	447	451.5	39.37693
Group=NiTi	225	456	451.5	39.37693

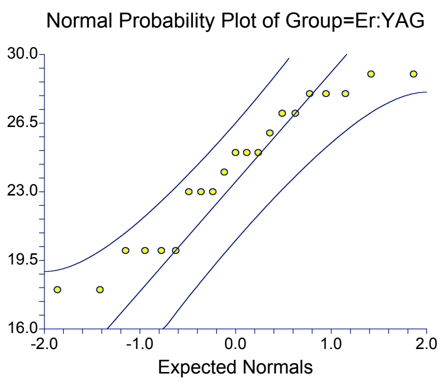
Number Sets of Ties = 9, Multiplicity Factor = 1392

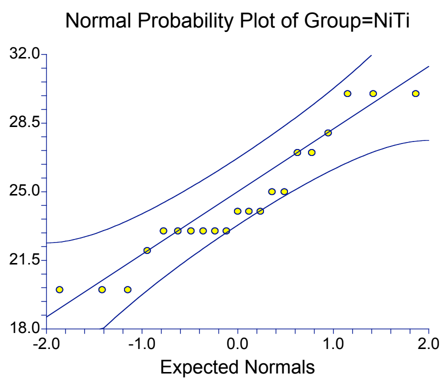
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	-0.1143	0.909016	Accept Ho	-0.1016	0.919088	Accept Ho
Diff<0	-0.1143	0.454508	Accept Ho	-0.1016	0.459544	Accept Ho
Diff>0	-0.1143	0.545492	Accept Ho	-0.1270	0.550521	Accept Ho

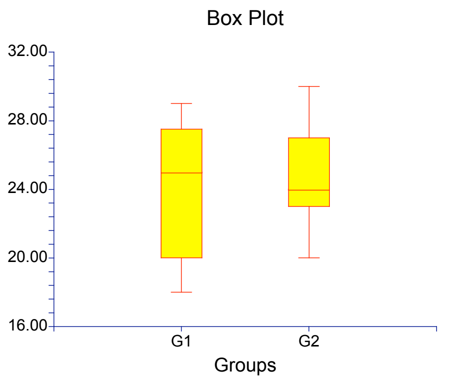
Plots Section











Er:YAG v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=Er:YAG	21	24.09524	3.618076	0.789529	21.78278	26.4077
Group=Unprepared	21	20.76191	3.03158	0.661545	18.8243	22.69951

Note: T-alpha (Group=Er:YAG) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=Er:YAG)	-0.6355	0.525103	Cannot reject normality
Kurtosis Normality (Group=Er:YAG)	-1.7261	0.084332	Cannot reject normality
Omnibus Normality (Group=Er:YAG)	3.3832	0.184221	Cannot reject normality
Skewness Normality (Group=Unprepared)	-0.7222	0.470198	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.0868	0.930864	Cannot reject normality
Omnibus Normality (Group=Unprepared)	0.5290	0.767575	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.4244	0.435910	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.1618	0.287545	Cannot reject equal variances

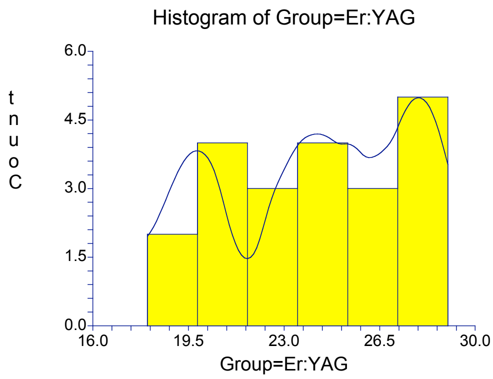
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

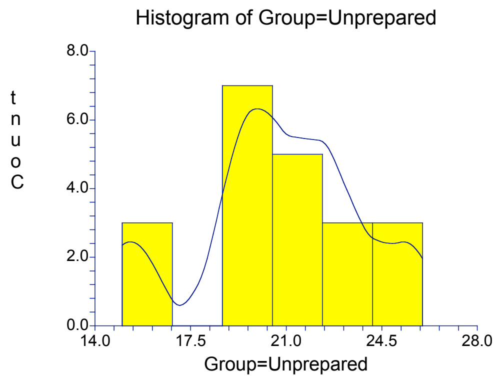
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=Er:YAG	330	561	451.5	39.49869
Group=Unprepared	111	342	451.5	39.49869

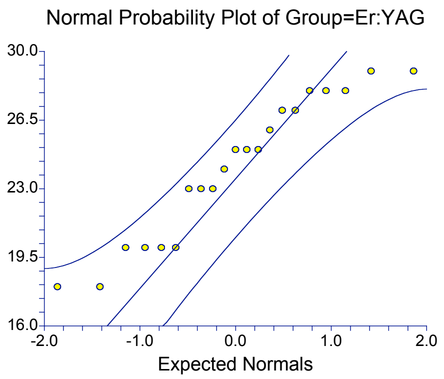
Number Sets of Ties = 12, Multiplicity Factor = 942

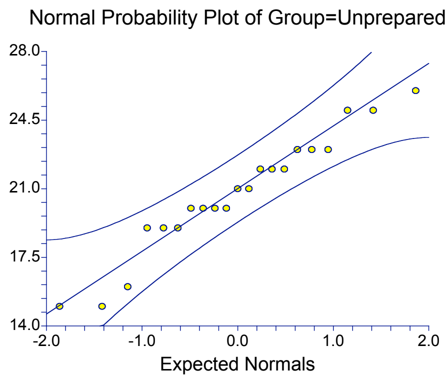
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	(Decision 0.83%)
Diff<>0	2.7722	0.005567	Reject Ho	2.7596	0.005787	Reject Ho
Diff<0	2.7722	0.997216	Accept Ho	2.7849	0.997323	Accept Ho
Diff>0	2.7722	0.002784	Reject Ho	2.7596	0.002894	Reject Ho

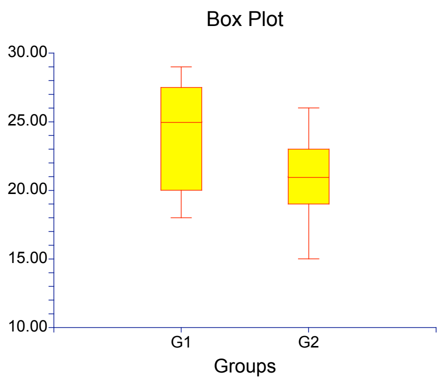
Plots Section











NiTi v Unprepared

Descriptive Statistics Section

Variable	Count	Mean	Standard Deviation	Standard Error	99% LCL of Mean	99% UCL of Mean
Group=NiTi	21	24.47619	3.140367	0.6852843	22.46906	26.48333
Group=Unprepared	21	20.76191	3.03158	0.661545	18.8243	22.69951

Note: T-alpha (Group=NiTi) = 2.9289, T-alpha (Group=Unprepared) = 2.9289

Tests of Assumptions Section

Assumption	Value	Probability	Decision(0.83%)
Skewness Normality (Group=NiTi)	1.0302	0.302930	Cannot reject normality
Kurtosis Normality (Group=NiTi)	-0.4460	0.655601	Cannot reject normality
Omnibus Normality (Group=NiTi)	1.2602	0.532549	Cannot reject normality
Skewness Normality (Group=Unprepared)	-0.7222	0.470198	Cannot reject normality
Kurtosis Normality (Group=Unprepared)	0.0868	0.930864	Cannot reject normality
Omnibus Normality (Group=Unprepared)	0.5290	0.767575	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.0731	0.876273	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.0062	0.937634	Cannot reject equal variances

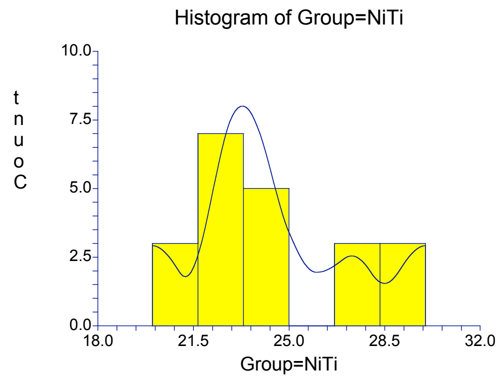
Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Medians

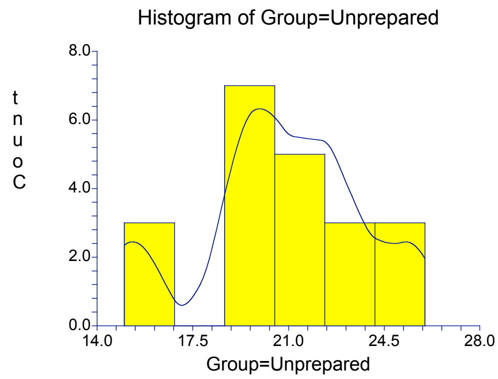
Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W
Group=NiTi	354.5	585.5	451.5	39.41106
Group=Unprepared	86.5	317.5	451.5	39.41106

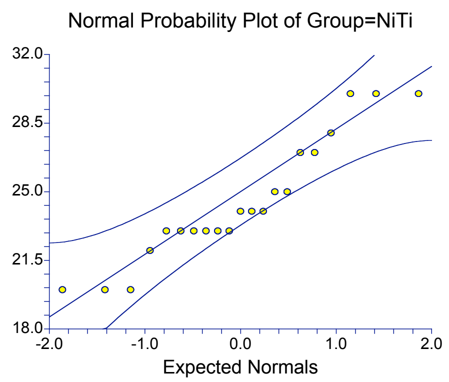
Number Sets of Ties = 10, Multiplicity Factor = 1266

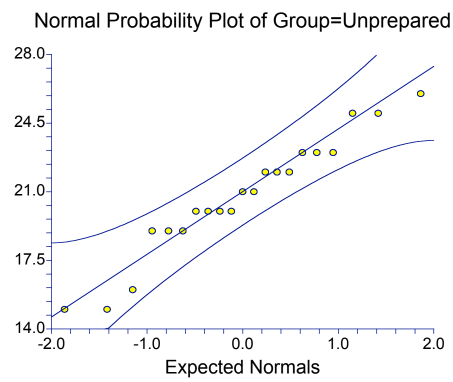
	Approximation Without Correction			Approximation With Correction		
Alternative Hypothesis	Z-Value	Prob Level	Decision (0.83%)	Z-Value	Prob Level	Decision (0.83%)
Diff<>0	3.4001	0.000674	Reject Ho	3.3874	0.000706	Reject Ho
Diff<0	3.4001	0.999663	Accept Ho	3.4127	0.999678	Accept Ho
Diff>0	3.4001	0.000337	Reject Ho	3.3874	0.000353	Reject Ho

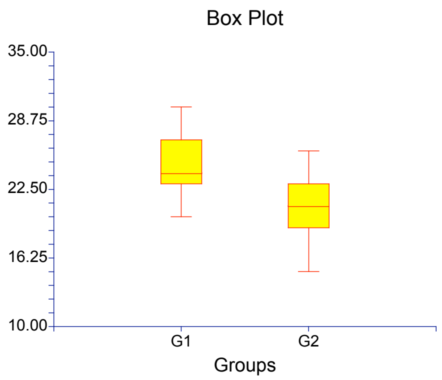
Plots Section











Result

The median overall total score for Er,Cr:YSGG is not significantly different from the Er:YAG, NiTi, or Unprepared groups.

The median overall total score for Er:YAG is not significantly different from NiTi.

The median overall total score for Er:YAG is significantly greater than the Unprepared group.

The median overall total score for NiTi is significantly greater than the Unprepared group.

Er:YAG > Unprepared

NiTi > Unprepared

Power analysis: 2 sample

Overall total (Er,Cr:YSGG v Er:YAG)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.28901	50	50	1.000	0.00830	0.71099	22.6	24.1	3.6	3.6
0.62045	100	100	1.000	0.00830	0.37955	22.6	24.1	3.6	3.6
0.83368	150	150	1.000	0.00830	0.16632	22.6	24.1	3.6	3.6
0.93663	200	200	1.000	0.00830	0.06337	22.6	24.1	3.6	3.6
0.97825	250	250	1.000	0.00830	0.02175	22.6	24.1	3.6	3.6
0.99312	300	300	1.000	0.00830	0.00688	22.6	24.1	3.6	3.6

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

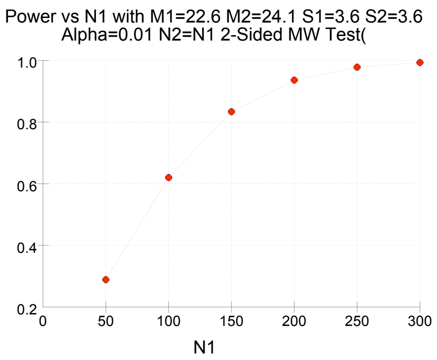
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 50 and 50 achieve 29% power to detect a difference of -1.5 between the null hypothesis that both group means are 22.6 and the alternative hypothesis that the mean of group 2 is 24.1 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Overall total (Er,Cr:YSGG v NiTi)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.49971	50	50	1.000	0.00830	0.50029	22.6	24.5	3.6	3.6
0.86266	100	100	1.000	0.00830	0.13734	22.6	24.5	3.6	3.6
0.97326	150	150	1.000	0.00830	0.02674	22.6	24.5	3.6	3.6
0.99583	200	200	1.000	0.00830	0.00417	22.6	24.5	3.6	3.6
0.99945	250	250	1.000	0.00830	0.00055	22.6	24.5	3.6	3.6
0.99993	300	300	1.000	0.00830	0.00007	22.6	24.5	3.6	3.6

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

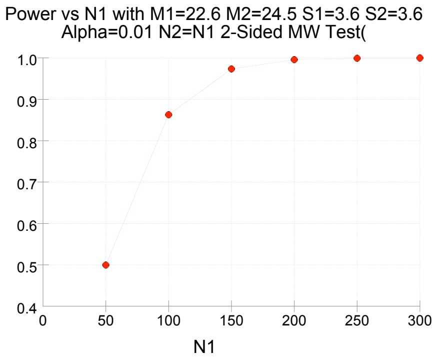
S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 50 and 50 achieve 50% power to detect a difference of -1.9 between the null hypothesis that both group means are 22.6 and the alternative

hypothesis that the mean of group 2 is 24.5 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Overall total (Er,Cr:YSGG v Unprepred)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.44448	50	50	1.000	0.00830	0.55552	22.6	20.8	3.6	3.6
0.81485	100	100	1.000	0.00830	0.18515	22.6	20.8	3.6	3.6
0.95453	150	150	1.000	0.00830	0.04547	22.6	20.8	3.6	3.6
0.99087	200	200	1.000	0.00830	0.00913	22.6	20.8	3.6	3.6
0.99841	250	250	1.000	0.00830	0.00159	22.6	20.8	3.6	3.6
0.99975	300	300	1.000	0.00830	0.00025	22.6	20.8	3.6	3.6

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

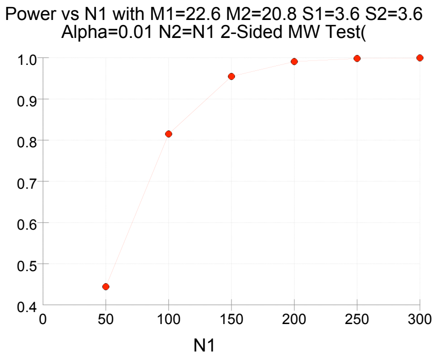
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 50 and 50 achieve 44% power to detect a difference of 1.8 between the null hypothesis that both group means are 22.6 and the alternative hypothesis that the mean of group 2 is 20.8 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Overall total (Er:YAG v NiTi)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80018	1964	1964	1.000	0.00830	0.19982	24.1	24.5	3.6	3.6

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 1964 and 1964 achieve 80% power to detect a difference of -0.4 between the null hypothesis that both group means are 24.1 and the alternative

hypothesis that the mean of group 2 is 24.5 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Debris total (Er,Cr:YSGG v Er:YAG)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.40195	50	50	1.000	0.00830	0.59805	12.9	14.0	2.3	2.3
0.77102	100	100	1.000	0.00830	0.22898	12.9	14.0	2.3	2.3
0.93348	150	150	1.000	0.00830	0.06652	12.9	14.0	2.3	2.3
0.98394	200	200	1.000	0.00830	0.01606	12.9	14.0	2.3	2.3
0.99661	250	250	1.000	0.00830	0.00339	12.9	14.0	2.3	2.3
0.99935	300	300	1.000	0.00830	0.00065	12.9	14.0	2.3	2.3

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

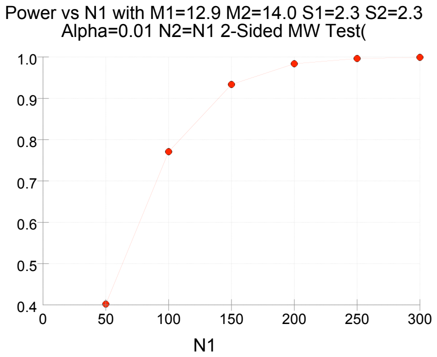
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 50 and 50 achieve 40% power to detect a difference of -1.1 between the null hypothesis that both group means are 12.9 and the alternative hypothesis that the mean of group 2 is 14.0 with known group standard deviations of 2.3 and 2.3 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Debris total (Er,Cr:YSGG v NiTi)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.13515	100	100	1.000	0.00830	0.86485	12.9	12.4	2.3	2.3
0.32071	200	200	1.000	0.00830	0.67929	12.9	12.4	2.3	2.3
0.50912	300	300	1.000	0.00830	0.49088	12.9	12.4	2.3	2.3
0.66813	400	400	1.000	0.00830	0.33187	12.9	12.4	2.3	2.3
0.78746	500	500	1.000	0.00830	0.21254	12.9	12.4	2.3	2.3
0.86986	600	600	1.000	0.00830	0.13014	12.9	12.4	2.3	2.3

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

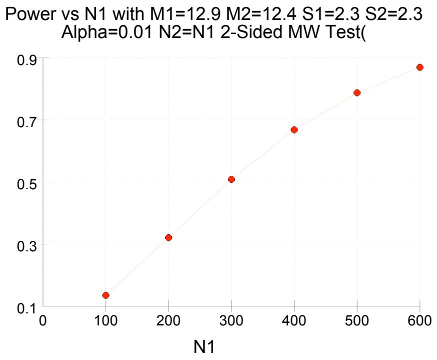
S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 100 and 100 achieve 14% power to detect a difference of 0.5 between the null hypothesis that both group means are 12.9 and the alternative

hypothesis that the mean of group 2 is 12.4 with known group standard deviations of 2.3 and 2.3 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Debris total (Er,Cr:YSGG v Unprepared)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.13918	10	10	1.000	0.00830	0.86082	12.9	11.3	2.3	2.3
0.33005	20	20	1.000	0.00830	0.66995	12.9	11.3	2.3	2.3
0.52178	30	30	1.000	0.00830	0.47822	12.9	11.3	2.3	2.3
0.68133	40	40	1.000	0.00830	0.31867	12.9	11.3	2.3	2.3
0.79917	50	50	1.000	0.00830	0.20083	12.9	11.3	2.3	2.3
0.87913	60	60	1.000	0.00830	0.12087	12.9	11.3	2.3	2.3
0.93002	70	70	1.000	0.00830	0.06998	12.9	11.3	2.3	2.3
0.96080	80	80	1.000	0.00830	0.03920	12.9	11.3	2.3	2.3
0.97867	90	90	1.000	0.00830	0.02133	12.9	11.3	2.3	2.3
0.98868	100	100	1.000	0.00830	0.01132	12.9	11.3	2.3	2.3

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

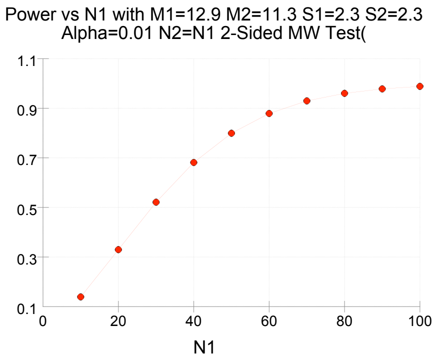
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 10 and 10 achieve 14% power to detect a difference of 1.6 between the null hypothesis that both group means are 12.9 and the alternative hypothesis that the mean of group 2 is 11.3 with known group standard deviations of 2.3 and 2.3 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Debris total (Er:YAG v NiTi)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.13918	10	10	1.000	0.00830	0.86082	14.0	12.4	2.3	2.3
0.33005	20	20	1.000	0.00830	0.66995	14.0	12.4	2.3	2.3
0.52178	30	30	1.000	0.00830	0.47822	14.0	12.4	2.3	2.3
0.68133	40	40	1.000	0.00830	0.31867	14.0	12.4	2.3	2.3
0.79917	50	50	1.000	0.00830	0.20083	14.0	12.4	2.3	2.3
0.87913	60	60	1.000	0.00830	0.12087	14.0	12.4	2.3	2.3
0.93002	70	70	1.000	0.00830	0.06998	14.0	12.4	2.3	2.3
0.96080	80	80	1.000	0.00830	0.03920	14.0	12.4	2.3	2.3
0.97867	90	90	1.000	0.00830	0.02133	14.0	12.4	2.3	2.3
0.98868	100	100	1.000	0.00830	0.01132	14.0	12.4	2.3	2.3

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

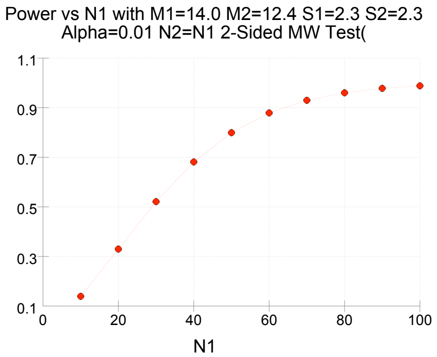
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 10 and 10 achieve 14% power to detect a difference of 1.6 between the null hypothesis that both group means are 14.0 and the alternative hypothesis that the mean of group 2 is 12.4 with known group standard deviations of 2.3 and 2.3 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Debris total (NiTi v Unprepared)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.40195	50	50	1.000	0.00830	0.59805	12.4	11.3	2.3	2.3
0.77102	100	100	1.000	0.00830	0.22898	12.4	11.3	2.3	2.3
0.93348	150	150	1.000	0.00830	0.06652	12.4	11.3	2.3	2.3
0.98394	200	200	1.000	0.00830	0.01606	12.4	11.3	2.3	2.3
0.99661	250	250	1.000	0.00830	0.00339	12.4	11.3	2.3	2.3
0.99935	300	300	1.000	0.00830	0.00065	12.4	11.3	2.3	2.3

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

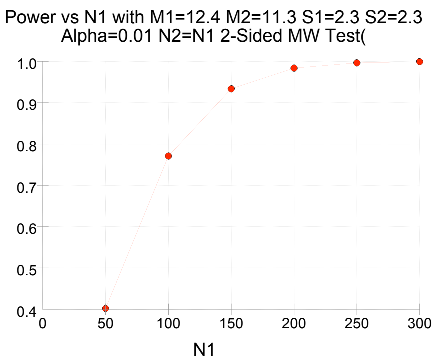
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 50 and 50 achieve 40% power to detect a difference of 1.1 between the null hypothesis that both group means are 12.4 and the alternative hypothesis that the mean of group 2 is 11.3 with known group standard deviations of 2.3 and 2.3 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Smear total (Er,Cr:YSGG v Er:YAG)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80009	5097	5097	1.000	0.00830	0.19991	9.8	10.0	2.9	2.9

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

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Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 5097 and 5097 achieve 80% power to detect a difference of -0.2 between the null hypothesis that both group means are 9.8 and the alternative hypothesis that the mean of group 2 is 10.0 with known group standard deviations of 2.9 and 2.9 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Smear total (Er,Cr:YSGG v Unprepared)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.80038	1275	1275	1.000	0.00830	0.19962	9.8	9.4	2.9	2.9

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 1275 and 1275 achieve 80% power to detect a difference of 0.4 between the null hypothesis that both group means are 9.8 and the alternative hypothesis that the mean of group 2 is 9.4 with known group standard deviations of 2.9 and 2.9 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Smear total (Er:YAG v NiTi)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.15378	10	10	1.000	0.00830	0.84622	10.0	12.1	2.9	2.9
0.36329	20	20	1.000	0.00830	0.63671	10.0	12.1	2.9	2.9
0.56551	30	30	1.000	0.00830	0.43449	10.0	12.1	2.9	2.9
0.72536	40	40	1.000	0.00830	0.27464	10.0	12.1	2.9	2.9
0.83672	50	50	1.000	0.00830	0.16328	10.0	12.1	2.9	2.9
0.90769	60	60	1.000	0.00830	0.09231	10.0	12.1	2.9	2.9
0.94996	70	70	1.000	0.00830	0.05004	10.0	12.1	2.9	2.9
0.97382	80	80	1.000	0.00830	0.02618	10.0	12.1	2.9	2.9
0.98672	90	90	1.000	0.00830	0.01328	10.0	12.1	2.9	2.9
0.99345	100	100	1.000	0.00830	0.00655	10.0	12.1	2.9	2.9

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

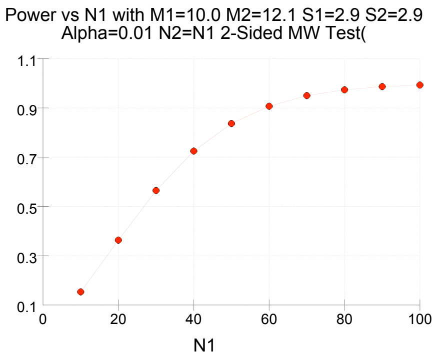
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 10 and 10 achieve 15% power to detect a difference of -2.1 between the null hypothesis that both group means are 10.0 and the alternative hypothesis that the mean of group 2 is 12.1 with known group standard deviations of 2.9 and 2.9 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Smear total (Er:YAG v Unprepared)

Numeric Results for Mann-Whitney Test (Uniform Distribution)

Null Hypothesis: Mean1=Mean2. Alternative Hypothesis: Mean1<>Mean2

The standard deviations were assumed to be known and equal.

Power	N1	N2	Allocation Ratio	Alpha	Beta	Mean1	Mean2	S1	S2
0.11969	100	100	1.000	0.00830	0.88031	10.0	9.4	2.9	2.9
0.28412	200	200	1.000	0.00830	0.71588	10.0	9.4	2.9	2.9
0.45793	300	300	1.000	0.00830	0.54207	10.0	9.4	2.9	2.9
0.61269	400	400	1.000	0.00830	0.38731	10.0	9.4	2.9	2.9
0.73621	500	500	1.000	0.00830	0.26379	10.0	9.4	2.9	2.9
0.82740	600	600	1.000	0.00830	0.17260	10.0	9.4	2.9	2.9

Report Definitions

Power is the probability of rejecting a false null hypothesis. Power should be close to one.

N1 and N2 are the number of items sampled from each population. To conserve resources, they should be small.

Alpha is the probability of rejecting a true null hypothesis. It should be small.

Beta is the probability of accepting a false null hypothesis. It should be small.

Mean1 is the mean of populations 1 and 2 under the null hypothesis of equality.

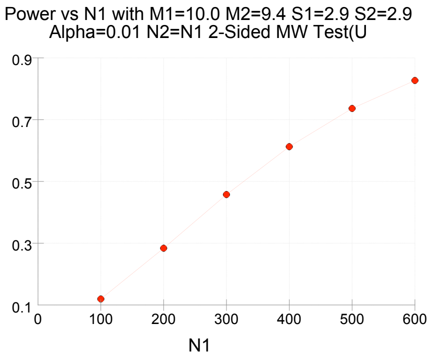
Mean2 is the mean of population 2 under the alternative hypothesis. The mean of population 1 is unchanged.

S1 and S2 are the population standard deviations. They represent the variability in the populations.

Summary Statements

Group sample sizes of 100 and 100 achieve 12% power to detect a difference of 0.6 between the null hypothesis that both group means are 10.0 and the alternative hypothesis that the mean of group 2 is 9.4 with known group standard deviations of 2.9 and 2.9 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.

Chart Section



Result

The following table summarises the above power analyses.

If a significant difference were to be found between all of the Overall total mean scores of the 4 groups then the appropriate power analysis would be for the comparison between Overall total (Er:YAG v NiTi). The following statements can be made:

1. Group sample sizes of 1964 and 1964 achieve 80% power to detect a difference of -0.4 between the null hypothesis that both group means are 24.1 and the alternative hypothesis that the mean of group 2 is 24.5 with known group standard deviations of 3.6 and 3.6 and with a significance level (alpha) of 0.00830 using a two-sided Mann-Whitney test assuming that the actual distribution is uniform.
2. N1 teeth/specimens = 1964/3 ≈ 655; total sample size = 1964/3*4 ≈ 2620

Comparison	Power	N1	N2	Alpha	Beta	Mean1	Mean2	S1	S2
Smear total (Er,Cr:YSGG v Er:YAG)	0.80009	5097	5097	0.00830	0.19991	9.8	10.0	2.9	2.9
Overall total (Er:YAG v NiTi)	0.80018	1964	1964	0.00830	0.19982	24.1	24.5	3.6	3.6
Smear total (Er,Cr:YSGG v Unprepared)	0.80038	1275	1275	0.00830	0.19962	9.8	9.4	2.9	2.9
Debris total (Er,Cr:YSGG v NiTi)	0.86986	600	600	0.00830	0.13014	12.9	12.4	2.3	2.3
Smear total (Er:YAG v Unprepared)	0.82740	600	600	0.00830	0.17260	10.0	9.4	2.9	2.9
Debris total (Er,Cr:YSGG v Er:YAG)	0.93348	150	150	0.00830	0.06652	12.9	14.0	2.3	2.3
Debris total (NiTi v Unprepared)	0.93348	150	150	0.00830	0.06652	12.4	11.3	2.3	2.3
Overall total (Er,Cr:YSGG v Er:YAG)	0.83368	150	150	0.00830	0.16632	22.6	24.1	3.6	3.6
Overall total	0.86266	100	100	0.00830	0.13734	22.6	24.5	3.6	3.6

Comparison	Power	N1	N2	Alpha	Beta	Mean1	Mean2	S1	S2
(Er,Cr:YSGG v NiTi)									
Overall total (Er,Cr:YSGG v Unprepred)	0.81485	100	100	0.00830	0.18515	22.6	20.8	3.6	3.6
Debris total (Er,Cr:YSGG v Unprepared)	0.87913	60	60	0.00830	0.12087	12.9	11.3	2.3	2.3
Debris total (Er:YAG v NiTi)	0.87913	60	60	0.00830	0.12087	14.0	12.4	2.3	2.3
Smear total (Er:YAG v NiTi)	0.83672	50	50	0.00830	0.16328	10.0	12.1	2.9	2.9

Inter-evaluator agreement

Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task. The following guidelines have been proposed for interpreting kappa. [1]

Kappa	Level of agreement
0.93-1.00	Excellent agreement
0.81-0.92	Very good agreement
0.61-0.8	Good agreement
0.41-0.6	Fair agreement
0.21-0.4	Slight agreement
0.01-0.2	Poor agreement
≤0.00	No agreement

Kappa reliability test was used to assess inter-evaluator agreement. The level of agreement varies considerably with the task. The following Table of Kappa reliability test between evaluators shows very good agreement [1].

Kappa	Evaluator 1 (DH)	Evaluator 2 (EB)	Evaluator 3 (MS)
Evaluator 1 (DH)	1.0	…	…
Evaluator 2 (EB)	0.926316	1.0	…
Evaluator 3 (MS)	0.926316	1.000000	1.0

Cross Tabulation Report

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DH v ER

Combined Report

Counts, Expected, Chi-Square

	Overall_ER		
Overall_DH	Up To 23	Over 23	Total
Up To 23	16	1	17
	9.71	7.29	17.00
	4.07	5.42	9.49
Over 23	0	11	11
	6.29	4.71	11.00
	6.29	8.38	14.67
Total	16	12	28
	16.00	12.00	28.00
	10.36	13.80	24.16

The number of rows with at least one missing value is 56

Chi-Square Statistics Section

Chi-Square	24.156863	
Degrees of Freedom	1	
Probability Level	0.000001	Reject Ho
Phi	0.928841	
Cramer's V	0.928841	
Pearson's Contingency Coefficient	0.680557	
Tschuprow's T	0.928841	
Lambda A .. Rows dependent	0.909091	
Lambda B .. Columns dependent	0.916667	
Symmetric Lambda	0.913043	
Kendall's tau-B	0.465608	
Kendall's tau-B (with correction for ties)	0.928841	
Kendall's tau-C	0.897959	
Gamma	1.000000	
Kappa reliability test	0.926316	
Kappa's standard error	0.188469	
Kappa's t value	4.914963	
McNemar's Test Statistic	1.000000	
McNemar's Degrees of Freedom	1	
McNemar's Probability Level	0.317311	

WARNING: At least one cell had an expected value less than 5.

DH v MS

Combined Report

Counts, Expected, Chi-Square

	Overall_DH		
Overall_MS	Up To 23	Over 23	Total
Up To 23	16	0	16
	9.71	6.29	16.00
	4.07	6.29	10.36
Over 23	1	11	12
	7.29	4.71	12.00
	5.42	8.38	13.80
Total	17	11	28
	17.00	11.00	28.00
	9.49	14.67	24.16

The number of rows with at least one missing value is 56

Chi-Square Statistics Section

Chi-Square	24.156863	
Degrees of Freedom	1	
Probability Level	0.000001	Reject Ho
Phi	0.928841	
Cramer's V	0.928841	
Pearson's Contingency Coefficient	0.680557	
Tschuprow's T	0.928841	
Lambda A .. Rows dependent	0.916667	
Lambda B .. Columns dependent	0.909091	
Symmetric Lambda	0.913043	
Kendall's tau-B	0.465608	
Kendall's tau-B (with correction for ties)	0.928841	
Kendall's tau-C	0.897959	
Gamma	1.000000	
Kappa reliability test	0.926316	
Kappa's standard error	0.188469	
Kappa's t value	4.914963	
McNemar's Test Statistic	1.000000	
McNemar's Degrees of Freedom	1	
McNemar's Probability Level	0.317311	

WARNING: At least one cell had an expected value less than 5.

MS v ER

Combined Report

Counts, Expected, Chi-Square

	Overall_ER		
Overall_MS	Up To 23	Over 23	Total
Up To 23	16	0	16
	9.14	6.86	16.00
	5.14	6.86	12.00
Over 23	0	12	12
	6.86	5.14	12.00
	6.86	9.14	16.00
Total	16	12	28
	16.00	12.00	28.00
	12.00	16.00	28.00

The number of rows with at least one missing value is 56

Chi-Square Statistics Section

Chi-Square	28.000000	
Degrees of Freedom	1	
Probability Level	0.000000	Reject Ho
Phi	1.000000	
Cramer's V	1.000000	
Pearson's Contingency Coefficient	0.707107	
Tschuprow's T	1.000000	
Lambda A .. Rows dependent	1.000000	
Lambda B .. Columns dependent	1.000000	
Symmetric Lambda	1.000000	
Kendall's tau-B	0.507937	
Kendall's tau-B (with correction for ties)	1.000000	
Kendall's tau-C	0.979592	
Gamma	1.000000	
Kappa reliability test	1.000000	
Kappa's standard error	0.188982	
Kappa's t value	5.291503	
McNemar's Test Statistic	0.000000	
McNemar's Degrees of Freedom	0	
McNemar's Probability Level	1.000000	

WARNING: At least one cell had a value less than 5.

References

1. Dawson B, Trapp RG. Basic & clinical biostatistics. 3rd edn. Boston: Lang Medical Books/McGraw-Hill Medical Publishing Division, 2001.

Appendix 12 Online Biolase™ clinical articles

Er,Cr laser has recently been approved by the US FDA for use in endodontics and is being promoted as suitable for preparing root canals.[1-4]

The following relevant clinical articles were accessed from the Biolase web site.[1-4]

YSGG laser root canal therapy [3]

YSGG Laser Root Canal Therapy

By William H. Chen, DMD, MAGD, FACD, FICD

According to the American Association of Endodontists (AAE), 17 million root canal procedures are performed every year. In a study also conducted by the AAE[1], a high percentage of adults surveyed described the root canal procedure as "painful" or "extremely painful." In view of these findings, the challenge for dentists is to discover new treatment modalities that are effective and provide better comfort to our patients. Furthermore, we do not want patients to avoid treatment out of fear, because serious complications can-and often do-arise. This can be addressed by providing them with a more gentle therapy.

Figure 1. A flexible fiber tip aids in preparing canals.

Figure 2. Patient presents with edema at the apical mucogingival tissue of tooth no. 27

Figure 3. Enamel and dentin are removed using the laser system to expose the pulp.

Figure 4. Laser fiber tip is used to enlarge the canal.

The challenge for dentists is to discover new treatment modalities that are effective and provide better comfort to our patients.

Dentistry has now been introduced to a new root canal treatment using the Er,Cr:YSGG (erbium, chromium: yttrium scandium gallium garnet) laser to provide additional important benefits to our patients. This new system should help reduce patient fear and improve their general attitude towards dentistry. The device that provides such a treatment is the Waterlase Hydrokinetic Hard and Soft tissue laser (Biolase Technology, Inc), the only laser system to receive FDA clearance for complete endodontic therapy involving enamel, dentin, pulp, and other root canal procedures. This laser uses specialized fibers of various diameters and lengths that provide access to effectively remove pulpal tissues and tooth structure from the root canal walls, and prepared the canal for opturation.

By utilizing the hydrokinetic process, in which water is energized by the YSGG laser photons to cause molecular excitation and localized microexpansions, hard tissues are removed cleanly and precisely with no thermal side effects. The energized particles are able to provide a gentle environment for removing tissue at the target point. High temperature which is a general concern with most laser systems, is not an issue with the Waterlase Hydrokinetic system. Studies have shown that the temperature of the pulpal tissue remains stable or drops approximately 2 C° below the normal temperature when the laser and spray reach the pulpal tissue.[2] The Waterlase Hydrokinetic system is already very versatile for both hard and soft tissue applications, and the YSGG laser endodontic application is yet another remarkable innovative discovery for dentistry.

In my practice today, I use the Waterlase Hydrokinetic endodontic system to perform root canal therapy in all anterior teeth and premolars that require root canal treatment. One remarkable finding that convinced me to start using this system in place of the conventional approach was the patients' consistent intraoperative and postoperative comfort levels. This finding parallels the benefits we generally see in YSGG Laser applications in dental surgeries and in tooth and bone procedures.

Initial findings from working with this system on extracted teeth demonstrated that utilizing the thin

and flexible fiber tips (Figure 1) was effective, and I was able to successfully debride, clean, and shape root canals in relatively straight and mildly curved canals. The results of YSGG Laser instrumentation showed that the canal shape established with this method of treatment was similar to the conventional approach. Following is a case report on one of the root canal clinical treatments that I performed using this new laser system.

The most important benefit of this revolutionary technology for endodontic treatments is the ease of using the system and the great degree of patient comfrot during and after the procedure.

CASE REPORT

The patient, a 64-year-old female with good general health, had been complaining about the presence of selling in the mucogingival area of the mandibular right cuspid. Clinical examination revealed edema at the apical mucogingival tissue of tooth No. 27 (Figure 2). The tooth was asymptomatic and slightly tender under percussion and palpitation. Vitality tests showed that the pulp was nonvital and probably necrotic. The periapical preoperative radiograph revealed that tooth No. 27 had a periapical lesion. Radiolucency around the apex of the tooth was also noted. The diagnosis was periapical abscess of endodontic origin. The treatment plan was root canal therapy using the Waterlase Hydrokinetic system as the modality of choice.

Because the infected tooth was asymptomatic, I decided to perform the procedure without local anesthesia. Although this particular case as completed without anesthesia, I have used anesthesia in other cases. Further studies will determine how frequently YSGG laser endodontic cases can be performed without anesthesia. Access opening was made using the laser system to remove the enamel and dentin to expose the pulp (Figure 3). The Pulpotomy was performed at soft tissue settings. The patient did not experience any pain during the access opening and pulpotomy.

To begin, I used small K files to establish the working length. I started the initial preparation with the Waterlase Hydrokinetic system using the thinnest fiber tip at low power settings in combination with an air and water spray. The laser fiber tip was used to enlarge the canal (Fig.4). At the same time, decontamination of the canal was induced by YSGG laser photons. This first procedure was followed by the next size fiber, utilized to further enlarge and clean the canal. The procedure continued until the canal was debrided and cleaned to the working length, enabling a No. 35 K file to reach the apex. The shaping of the canal by the YSGG laser enabled a No. 60 K file to reach the middle third of the canal and to accommodate the gutta-percha points fitting the canal the working length. The canal was then dried with paper points and sealed with sealant and gutta percha.

The patient was very pleased with the treatment and quite surprised to find that there was minimal discomfort throughout the procedure. She was happy to leave the office without the numbness that normally follows mandibular block anesthesia. A prescription for antibiotics and pain medication was given before dismissing the patient. At the 24-hour postoperative telephone interview, the patient informed me that she had no complications such as swelling or discomfort, and that she had no need to use the pain medication.

CONCLUSION

From my experience with the Waterlase Hydrokinetic system on patients, the most important benefit of this revolutionary technology for endodontic treatments is the ease of using the system and the great degree of patient comfort during and after the procedure. Also, I have found a reduced need-and in some cases no need at all-for prescription pain medication. Furthermore, postoperative complications such as inflammation, swelling, and pain were significantly reduced. In addition, the possibility exists that more root canal therapy can be performed without any anesthesia. Also, due to the antibacterial effect of the YSGG laser, it is my opinion that this will lead to a reduction in the need for postoperative antibiotics. All of these factors help to improved patients' attitudes toward dentistry.

REFERENCES

1. Pain jokes no laughing matter to root canal specialists. Press release. American Association of Endodontists. March 29, 2000.

2. Rizoiu, I. Kohanghadosh, F., Kimmel, Al. Eversole, LR. Pulpal thermal responses to an Er,Cr:YSGG pulsed laser hydrokinetic system. Oral Surg Oral Med Oral Pathol Oral Radiol

Er,Cr:YSGG laser root canal procedure [2]

Er,Cr:YSGG Laser Root Canal Procedure: Case Report

*William H. Chen, DMD**

The hydrokinetic laser system of the Er,Cr:YSGG (YSGG) (Erbium, Chromium, Yttrium, Scandium, Gallium, Garnet) has demonstrated effective removal of biocalcified intraoral tissues (eg, enamel, dentin, cementum, bone)[1,2] as well as soft tissues.[2] The effectiveness of this laser wavelength in endodontic applications is based on its prior clinical success in both hard and soft tissue applications. In order to understand how this laser works, one needs to understand the principles behind hydrokinetics.

The YSGG energy is able to interact with water droplets at the tissue surface to create water molecule excitation that causes droplet microexpansion and propulsion. As a result, hard tissue can be removed cleanly and precisely, without detrimental thermal side effects.[3] In soft tissue surgery, the cutting is primarily performed through direct YSGG laser energy, resulting in precise removal of these tissues.[4] As the water molecules from within these tissues absorb the laser energy, disruption of the soft tissue occurs.

In a position statement on the uses of lasers in dentistry, the American Association of Endodontists (AAE) presented a series of advantages and disadvantages of laser energy for use in root canal procedures.[5] In their recent report, the AAE recognized that laser energy can reduce the quantity of microorganisms,[6,7] remove the smear layer and dentin from the canal wall,[8] melt and resolidify the dentin to close tubular openings,[9] and may aid in welding toothlike materials to the resolidified walls resulting in denser root canal packing.[8]

However, the AAE also raised the following concerns related to the use of laser energy in root canal procedures:

- Root canal spaces are often curved in at least two dimensions. The laser fiber or fiber tip that is made of glass cannot be curved to follow the natural curvatures of the tooth root.[6]
- Elevations in temperature from the interactions involved between laser energy and tissue can char the canal space, damaging it to the point that the tooth may be lost.[10] These elevated temperatures may also extend to the other surfaces of the tooth, damaging the soft tissue that connects the tooth to the surrounding bone.

Since the publication of the AAE position statement on lasers in endodontics, the Food and Drug Administration (FDA) has completed its evaluation for efficacy and safety of the YSGG laser system and granted clearance for a hard tissue laser to perform complete root canal preparations. Due to its gentle mechanism of cutting, the YSGG laser system does not induce the detrimental thermal effects encountered in other laser systems. As a result, this endodontic system can be used to perform predictable, painless root canal therapy.

FIGURE 1. Preoperative facial view demonstrates a compromised maxillary central incisor upon presentation.

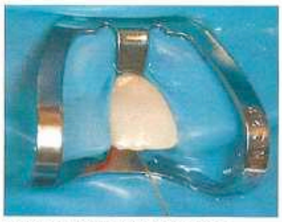

FIGURE 2. Once access opening is accomplished using the YSGG laser, a flexible endodontic fiber tip is used to desensitize, clean, and remove the pulpal and diseased dentin wall tissues.

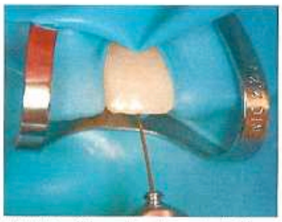

FIGURE 3. A larger diameter endodontic fiber tip is used to enlarge and shape the canal.

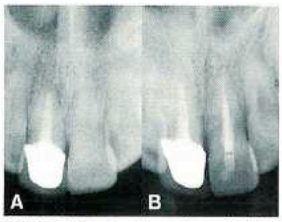

FIGURE 4A. Preoperative radiograph of the maxillary central incisor. **4B.** Postoperative radiograph following laser therapy demonstrates complete removal of the compromised tissues and successful endodontic treatment.

CASE PRESENTATION

A 48-year-old female patient presented with spontaneous pain in the maxillary left central incisor (tooth #9[21]). The patient had a history of trauma involving the anterior region, and tooth #9 was symptomatic to pressure, percussion, and cold stimuli. Heat stimulus produced delayed and prolonged pain over an extended duration. Radiographic evaluation revealed periapical irregularities and slight radiolucency. The diagnosis was irreversible pulpitis of tooth #9 and a root canal procedure was selected. The patient was apprehensive of dental procedures due to a dislike of injection anesthesia, and the YSGG laser was selected following thorough education and discussion.

Local anesthetic was not used for this procedure, and minimal laser energy was used to desensitize the tooth. Laser energy was applied to the periodontal sulcus and cementoenamel junction circumferentially. Low laser energy was then used to condition the enamel with gradually increased energy to ablate enamel and dentin until the pulp was exposed.[11,12] The patient did not experience any pain during the pulpotomy and laser energy was applied to desensitize, cut, clean, and remove the pulpal and diseased dentin wall tissues. The device was maneuvered in the canal until an estimated two thirds of the canal length was reached. The patient was checked periodically to determine if any discomfort was experienced, and the working length was established with a #15 K handfile and confirmed by a periapical radiograph. A rubber dam was placed, and the root canal procedure continued with cleaning and shaping. Larger diameter endodontic fiber tips were used sequentially from the thinnest to largest width in order to enlarge and achieve final preparation of the canal. This preparation was considered accomplished when a #35 K handfile was able to reach the entire working length and a #60 K handfile was able to reach the middle third of the canal. In this case, the K files were used only as measuring tools to establish that the canal was prepared for gutta percha obturation. At this point, the gutta percha master cone could also fit the canal to the working length. Paper absorbing points were used to dry the canal prior to placement of sealant and gutta percha. Neither postoperative pain nor swelling were evident at the 24-hour follow-up.

CONCLUSION

Minimal to no patient discomfort can be achieved intra- and postoperatively using contemporary YSGG technology. Additional benefits include reduced postoperative complications (eg, inflammation, swelling) and the reduced risk of infection. With the presence of the water spray and the specialized YSGG laser technology, it is possible to remove both soft and hard tissues in the root canal without causing damage to the periodontal tissue. Diseased soft and hard tissue in the canal can be precisely removed by laser energy. This innovative laser system (Waterlase, Biolase Technology, San Clemente, CA) is an attractive alternative to the conventional approach due to the direct benefits to our patients.

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Complete RCT using the Waterlase [4]

Technique Endodontics

Complete root canal therapy using the Waterlase YSGG all-tissue dental laser

By Dr. James Jesse. Information provided by Biolase Technology Inc.

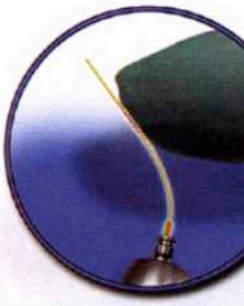

Fig. 1 A thin, flexible endo fiber tip eliminates infected tissue from a canal.

Following are step-by-step procedures for using the Waterlase YSGG all-tissue dental laser with flexible endo fiber tips (Fig. 1) to complete EndoLase root canal therapy. EndoLase therapy is a basic method of precisely and cleanly removing necrotic and infected tissue from root canals and for enlarging and tapering the canal to prepare for obturation. There are varying approaches to completing an EndoLase procedure, depending on personal technique.

Generally, using the laser to complete an EndoLase procedure provides very conservative treatment of the anatomy of the inside of the tooth. The existing anatomy can easily be followed, and there is no need to enlarge the canal any more than necessary.

Preparing access to the pulp chamber for pulpotomy and pulp removal

In most cases, there is no need to anesthetize the patient prior to conducting the procedure. (There are occasional circumstances where anesthetic is necessary.) Figure 2 is a pre-op view of the infected tooth.

1. Initially, use the 600-µm endo laser tip with very little laser energy to desensitize the tooth and to condition the enamel for removal (Fig. 3)
2. Next, increase the laser energy slightly, together with the air and water spray, to start ablating the enamel and dentin until the pulp of the infected tooth is exposed (Fig. 4)
3. Once the pulp is exposed, perform a traditional pulpotomy using the laser. *Note:* Typically, this is a good point to ask the patients if they have felt any pain or discomfort. Usually, the patient is very comfortable. (If they feel anything at this point, injecting anesthetic directly into the pulp may be necessary.)
4. Continue with the procedure using the thinnest endodontic fiber tip and gradually add laser energy. Desensitize and ablate the infected pulpal tissue and dentin until there is clear access to the canal (Fig. 5).

Cleaning and shaping the canal

1. Once access to the canal is gained, continue with the thinnest endodontic fiber tip and work to about two-thirds of the length of the diseased canal.
2. Determine the working length of the root with a #15 K-file (Fig. 6) and either a digital or traditional periapical x-ray before proceeding. *Note:* Usually, the patient still has not expressed any discomfort or pain.
3. Continue the procedure by cleaning and enlarging the middle third and apical end of the canal. Using a sequence of highly flexible fiber tips (from thinnest to thickest), gradually increase the laser energy and continue to clean and shape the canal to achieve final preparation.
4. Use a series of measurements, starting with the #30 K-file, to determine if the canal is ready for obturation. *Note:* If the #30 K-file can easily reach the working length of the canal, and no debris or material impedes the insertion of the file, the canal is ready for obturation.

Canal obturation

1. The gutta-percha master cone should fit into the entire working length of the canal. If so, the canal is ready for sealing.
2. Use paper absorbing points to thoroughly swab the canal of any moisture, as a precautionary step.
3. Use Ultradent's EndoRez (or a comparable sealant material) to seal the canal.
4. Insert one gutta-percha cone to allow for a pathway for a post or re-treatment. DPR

Fig. 2 The pre-op view of the infected tooth.

Fig. 3 Use the 600-µm tip for desensitizing and conditioning.

Fig. 4 Ablate enamel and dentin until pulp is exposed.

Fig. 5 The thinnest tip is used to clear infected tissue from the canal.

Fig. 6 Determine the working length using a #15 K-file.

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